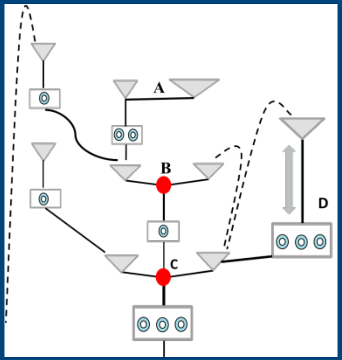
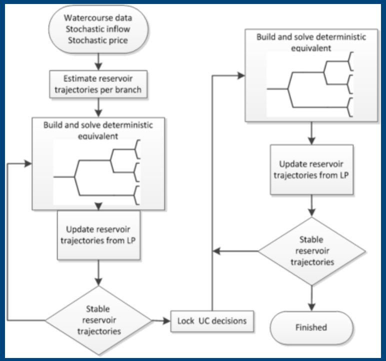
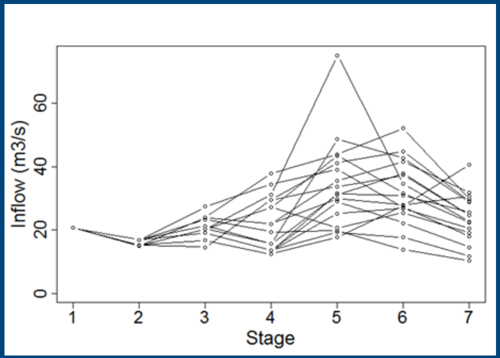
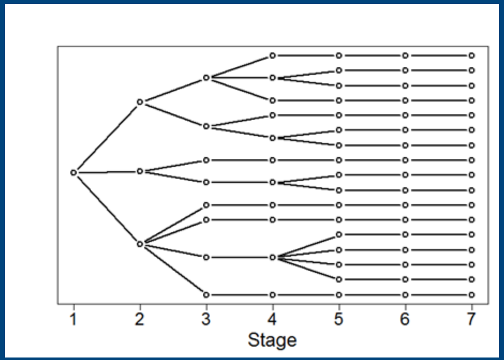








Stochastic short-term model = SHARM

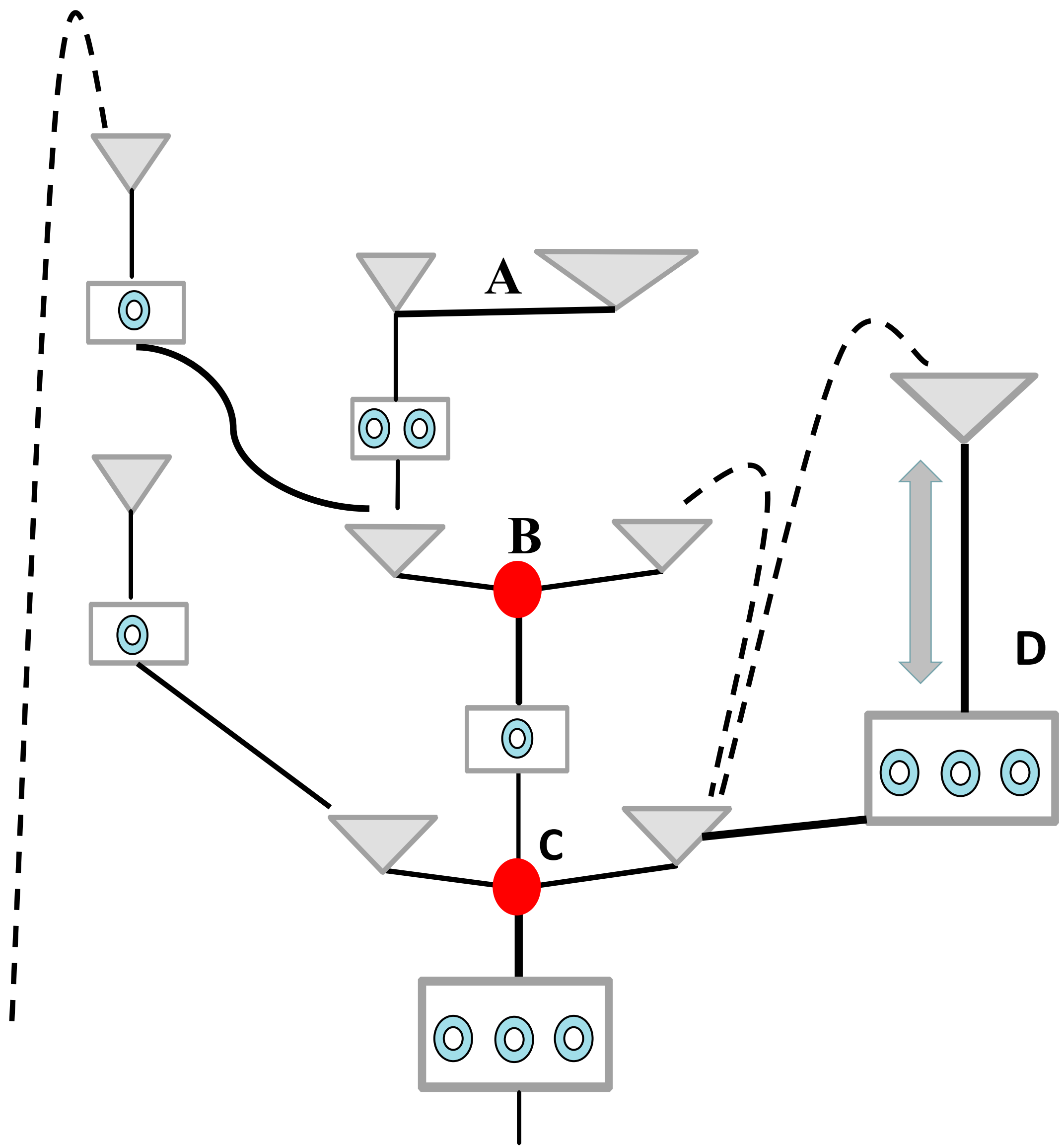
Concept

Example on results

Next step in the SHARM development

Brukermøte 2013, Michael Belsnes

Model concept



Found and implemented a modelling concept:

- **Done prototyping in GAMS**
- **Build a prototype for industry testing**

The concept is based on: Stochastic Successive Linear Programming (SSLP)

Has the potential to become as rich on details as the current SHOP model.

Model concept

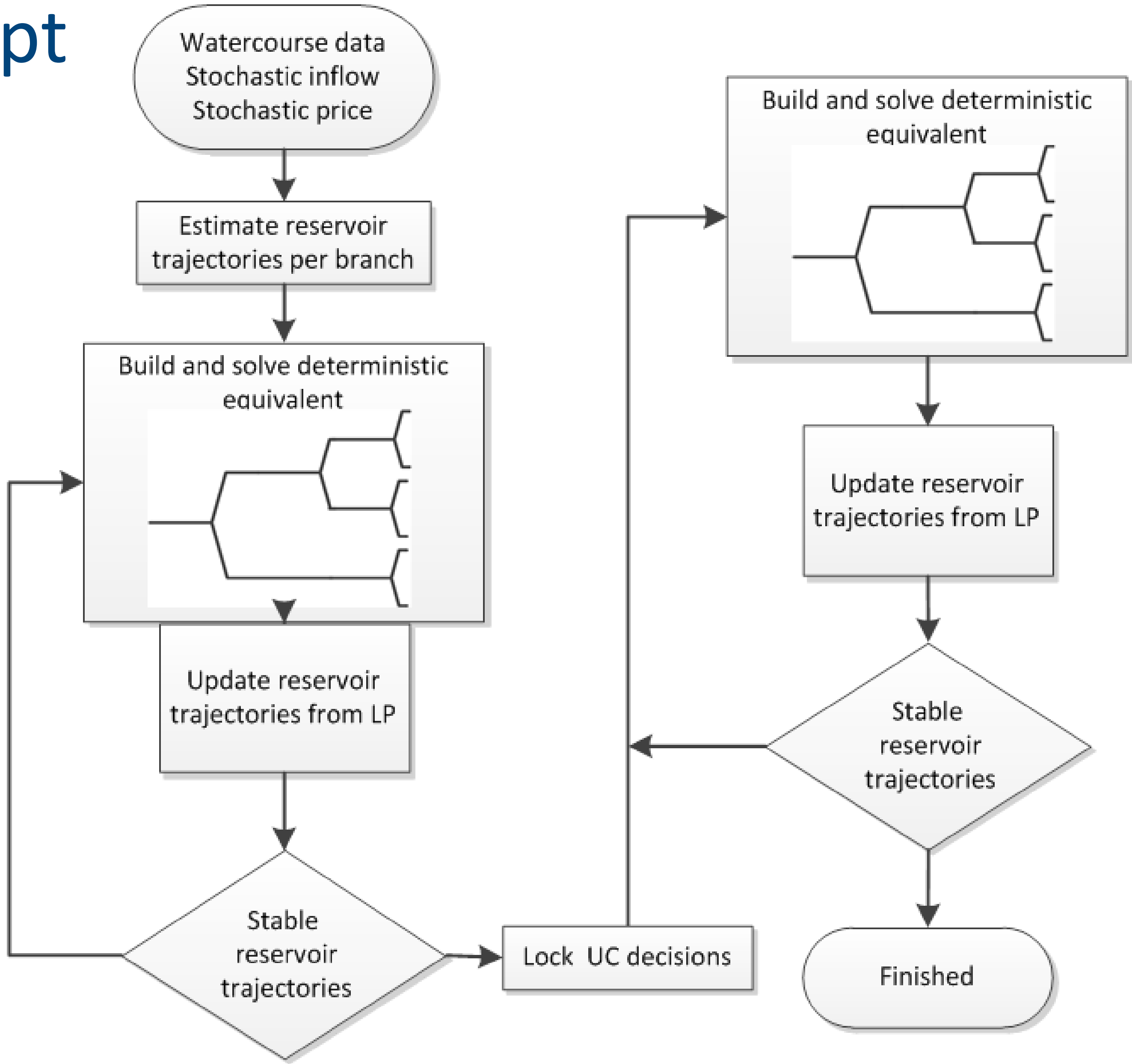
SSLP:

Stochastic

Successive

Linear

Programing



Prof of concept

Question one

Will the SSLP method converge towards the optimal solution?

Question two

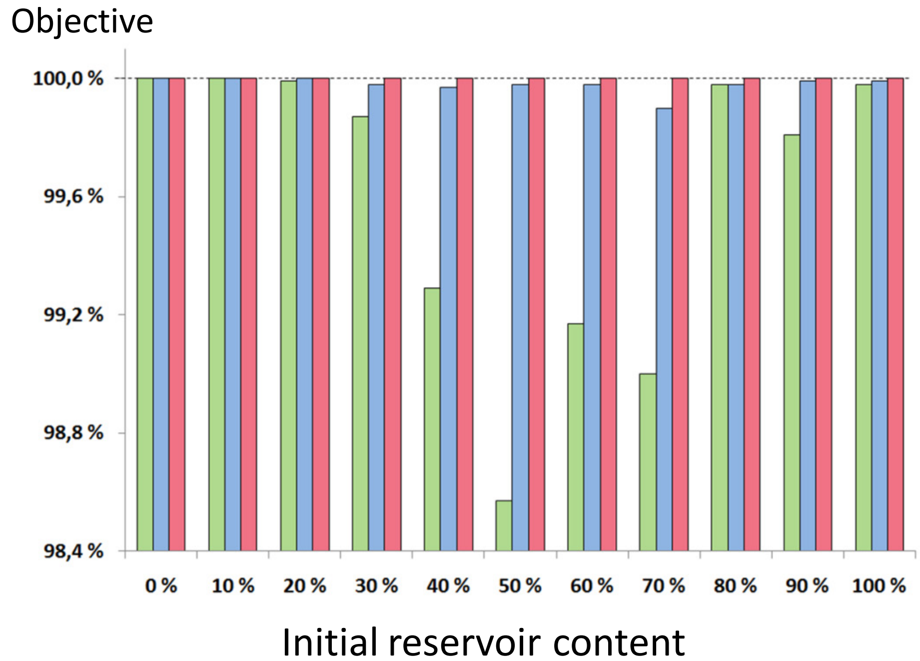
Will head optimization improve the solution, and how much?

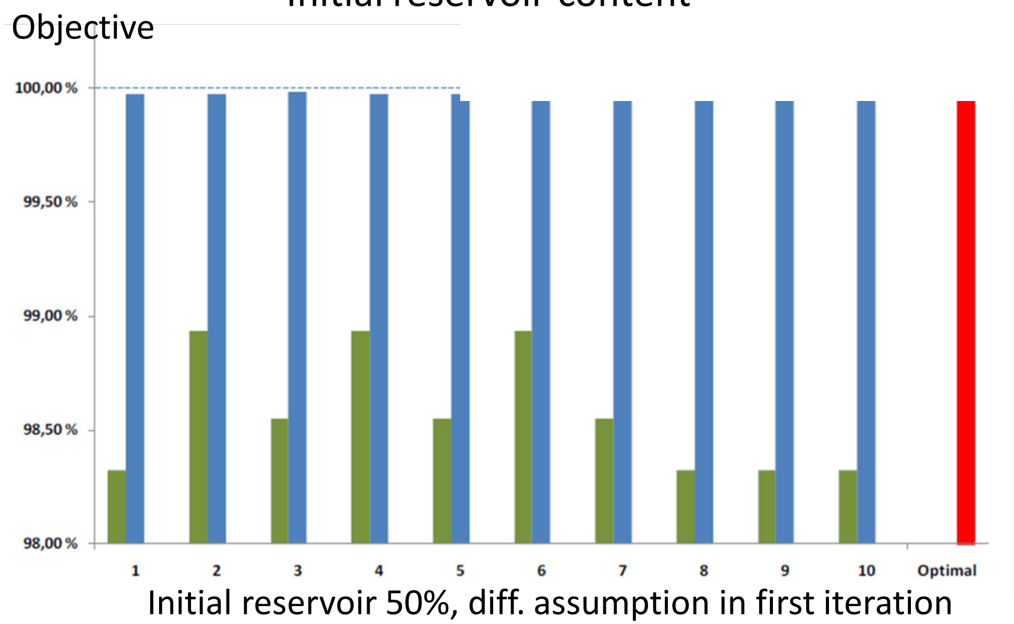
This test shows SSLP results -0.02% lower compared to the optimal solution but 0.5% better than standard successive linear programming.

Green: No head optimization

Blue: Head optimization

Red: Non-linear model (optimal)





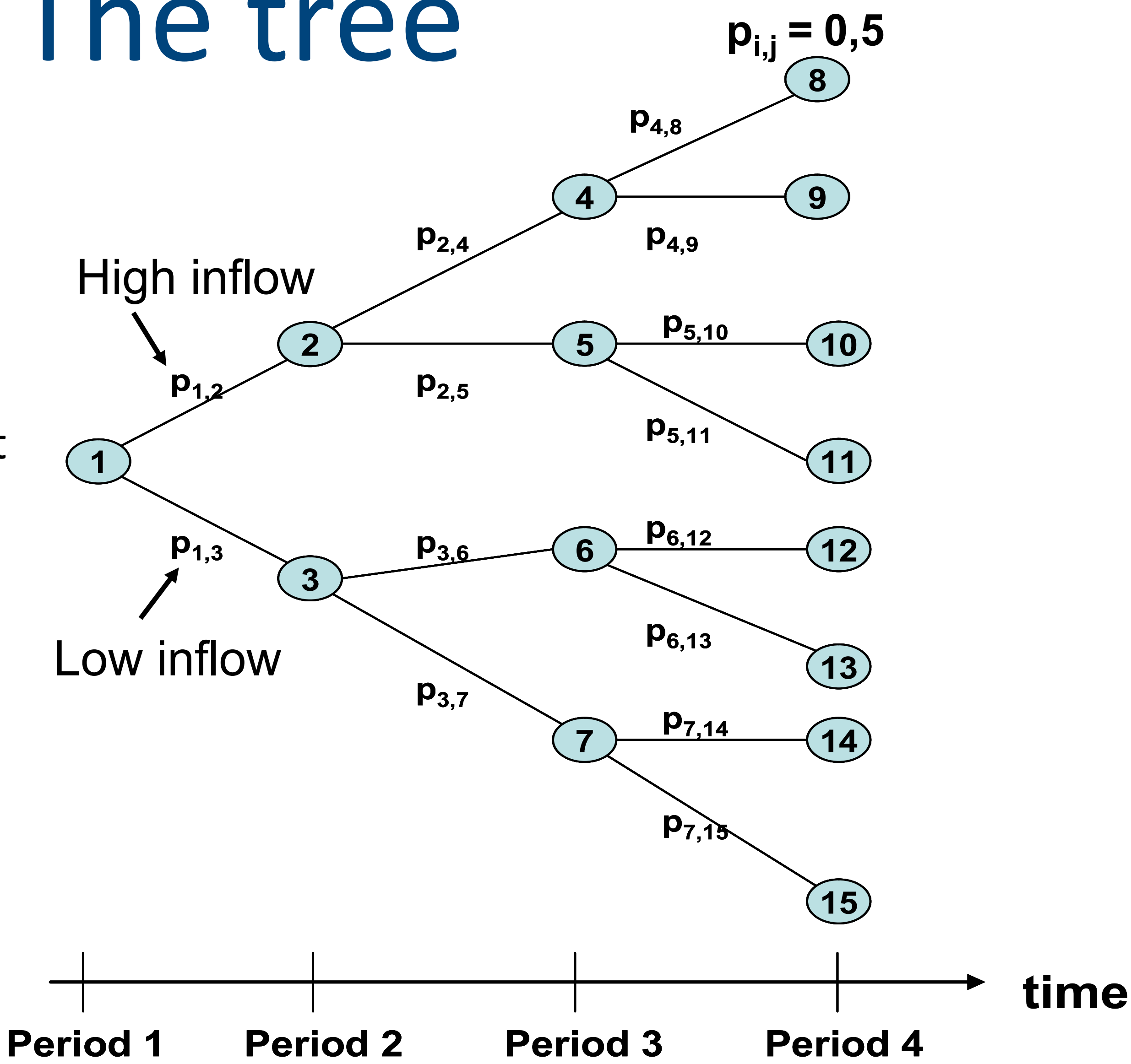
The tree

The method is based on construction
of a tree from any stochastic
parameter or event.

A tree can contain information about different stochastic variables.

A node can have 1-n branches and need not be symetric.

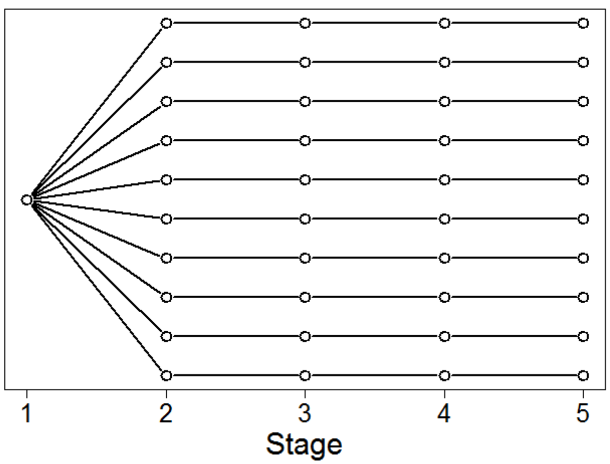
.... but a tree can rapidly grow very large, and that is a challenge



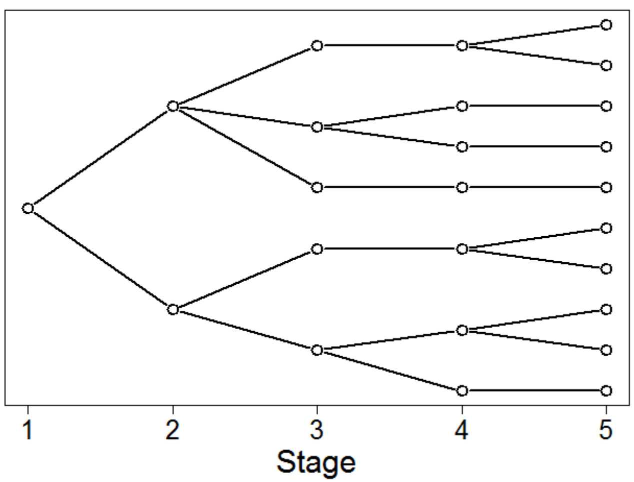
Tree construction and scenario reduction

1. Tree construction:
    - Input: A set of scenarios for **inflow** and/or **price**. Could be an ensemble prognosis, Monte Carlo simulation from statistical model.
    - Output: A scenario tree on a form that can be used in SHARM

Input:



Output:

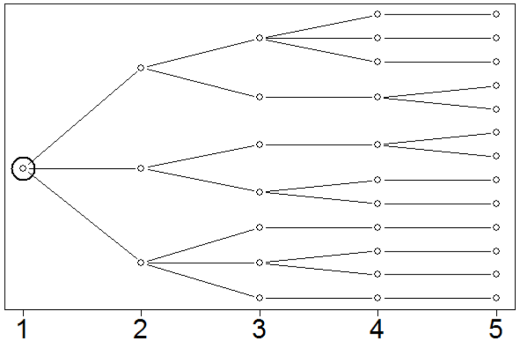


2. Scenario reduction:
    - Input: A large scenario tree giving unacceptable execution times in SHARM.
    - Output: A reduced scenario tree with similar properties as the small.

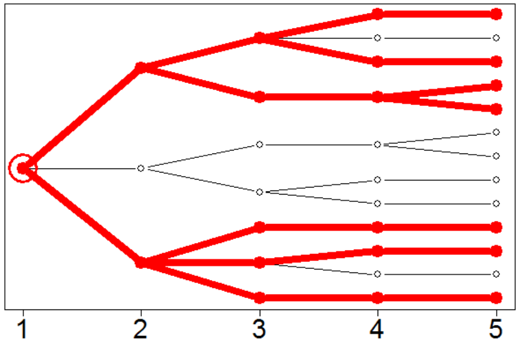
Evaluation of the effect of reducing the scenario tree

- Starting point: Full tree that reflects the information structure, and is assumed to be a good approximation to the predictive distribution
- Compute expected profit using the full tree, but for optimal decision based on reduced trees
- Using reduced trees: Optimal decisions are not obtained for all nodes of the full tree

Full tree:

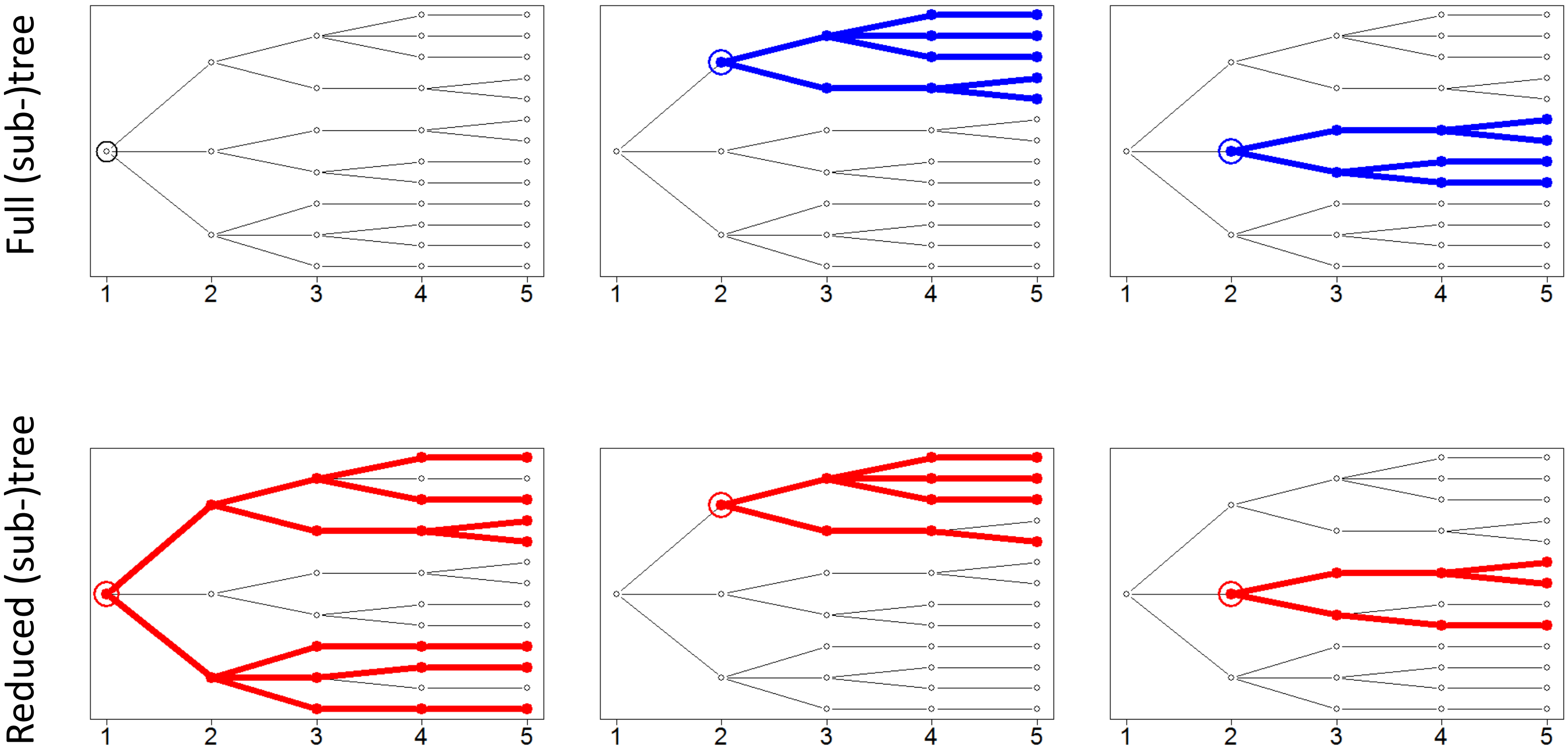


Reduced tree:



- **Evaluation approach**: Based on optimal first-stage decisions obtained for reduced trees, computed sequentially traversing the full tree

Evaluation approach



Example

- Single-reservoir hydropower system
- Uncertain inflow
- Deterministic spot price: Linearly increasing

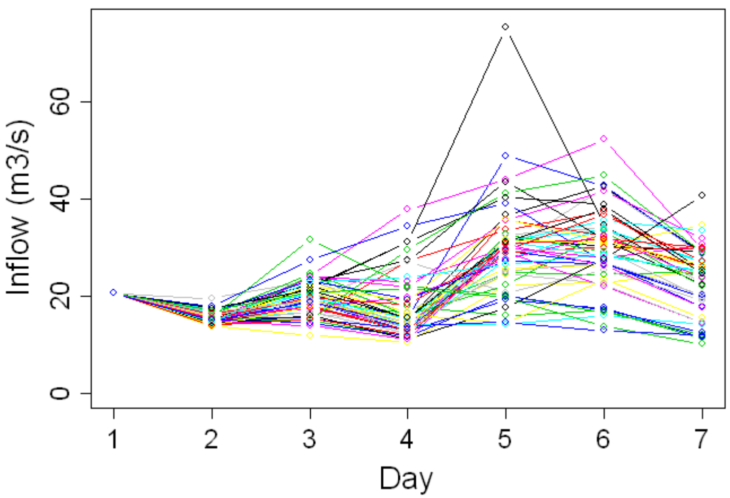
Maximize

$$\pi = \sum_{i \in I} \text{prob}_i \times \text{price}_i \times \text{generation}_i + \sum_{i \in I_{end}} \text{prob}_i \times \text{end value}_i$$

subject to

water balance for each node $i \in I$

other constraints



Initial inflow scenarios:

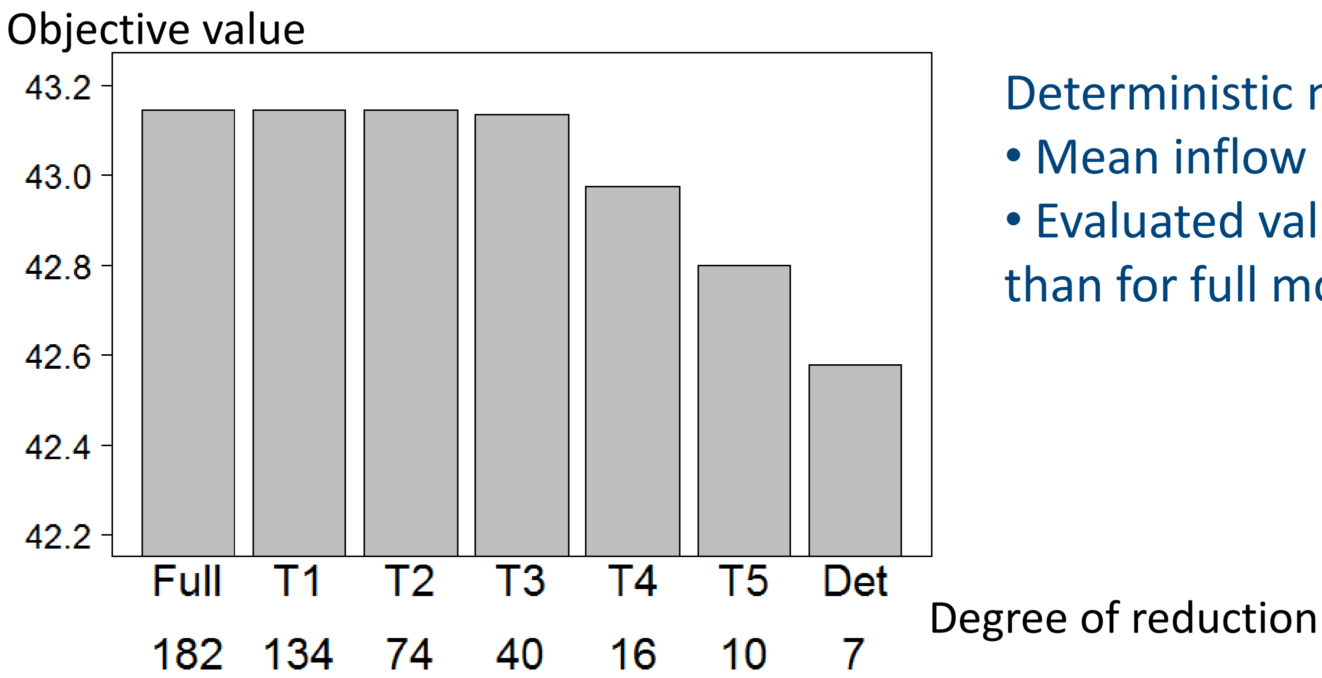
- Ensemble forecast from the HBV model
- 51 scenarios
- Daily time resolution
- Assume equal probability for all scenarios

Data provided by Agder Energy

Full tree = Reference scenario tree that reflects information structure:

- Generated from the initial scenarios by the tree construction feature of SCENRED-2

Results: Objective function value



Deterministic model:

- Mean inflow
- Evaluated value is 1.3% lower than for full model

Tree	Full tree	T1	T2	T3	T4	T5	Determ
Scenarios	51	35	17	8	3	2	1
Nodes	182	134	74	40	16	10	7

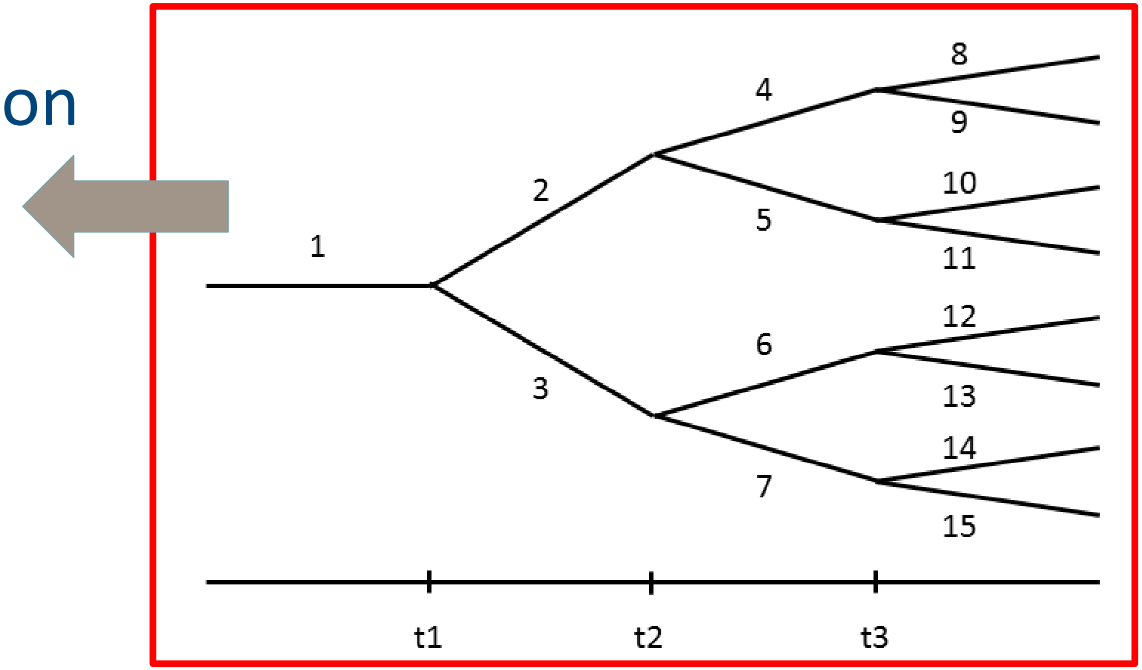
Some results:

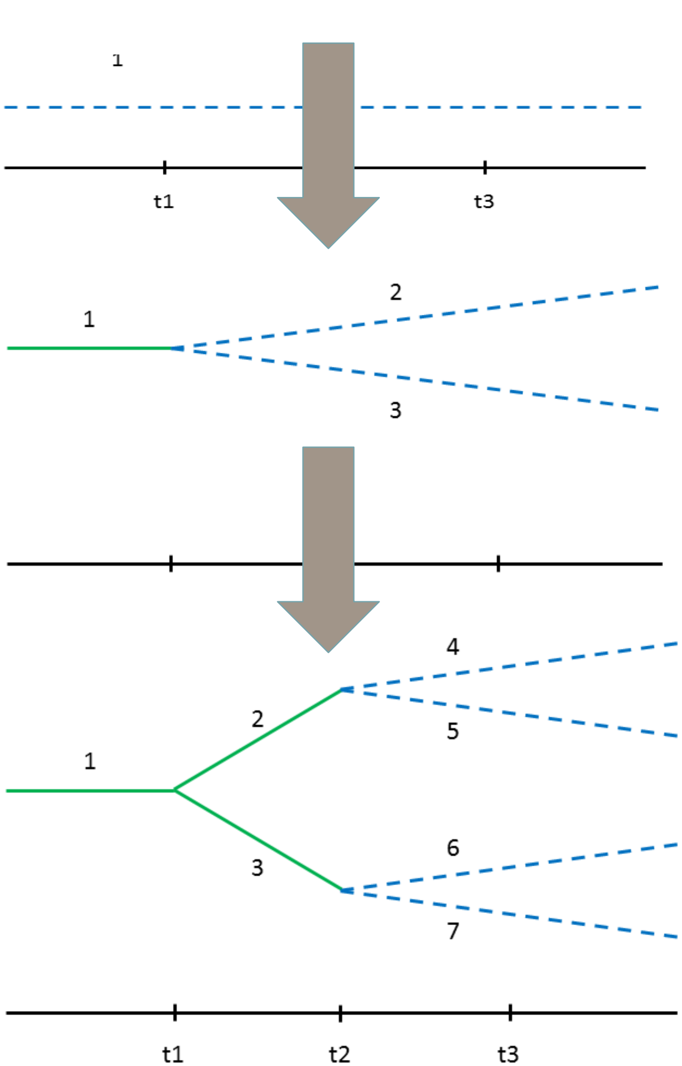
- Initial prototype in GAMS showed improvement of the stochastic model over the deterministic model in the interval 0.1 to 6%

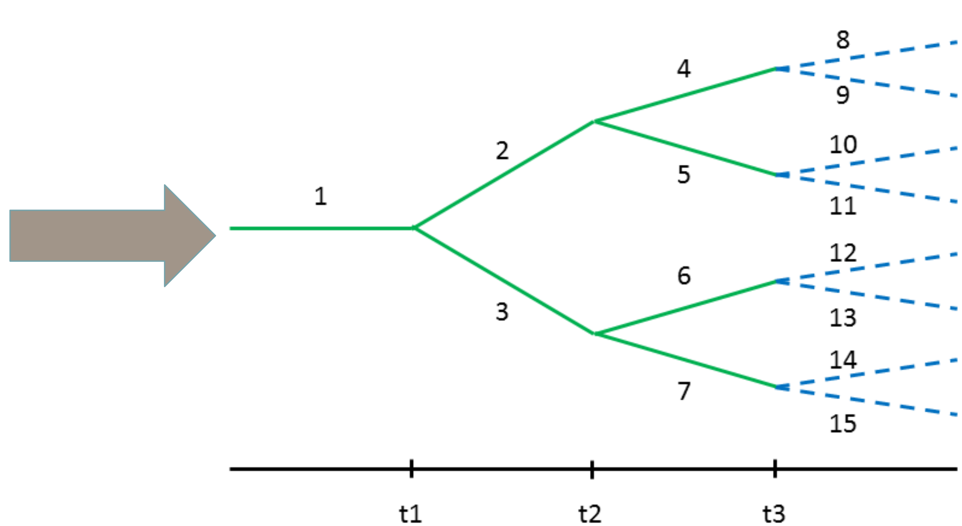
- We have tested that simultaneous optimization towards a stochastic spot and a stochastic RK market showed significant difference in strategy for utilization of the system. The economic comparison to the case of bidding into the RK market after spot clearance showed only minor differences.

- Testing the SHARM prototype in our "laboratory" shows a 0.01-2.5 % improvement compared to deterministic SHOP calculations.

Deterministic simulation

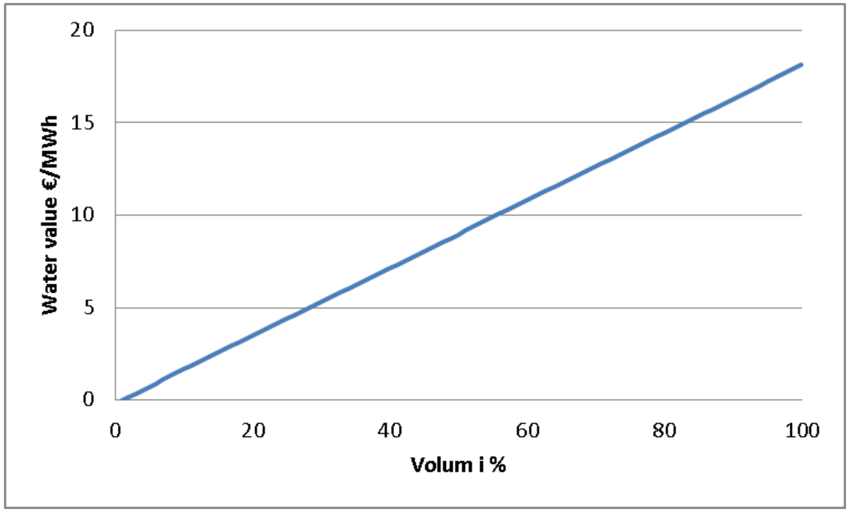


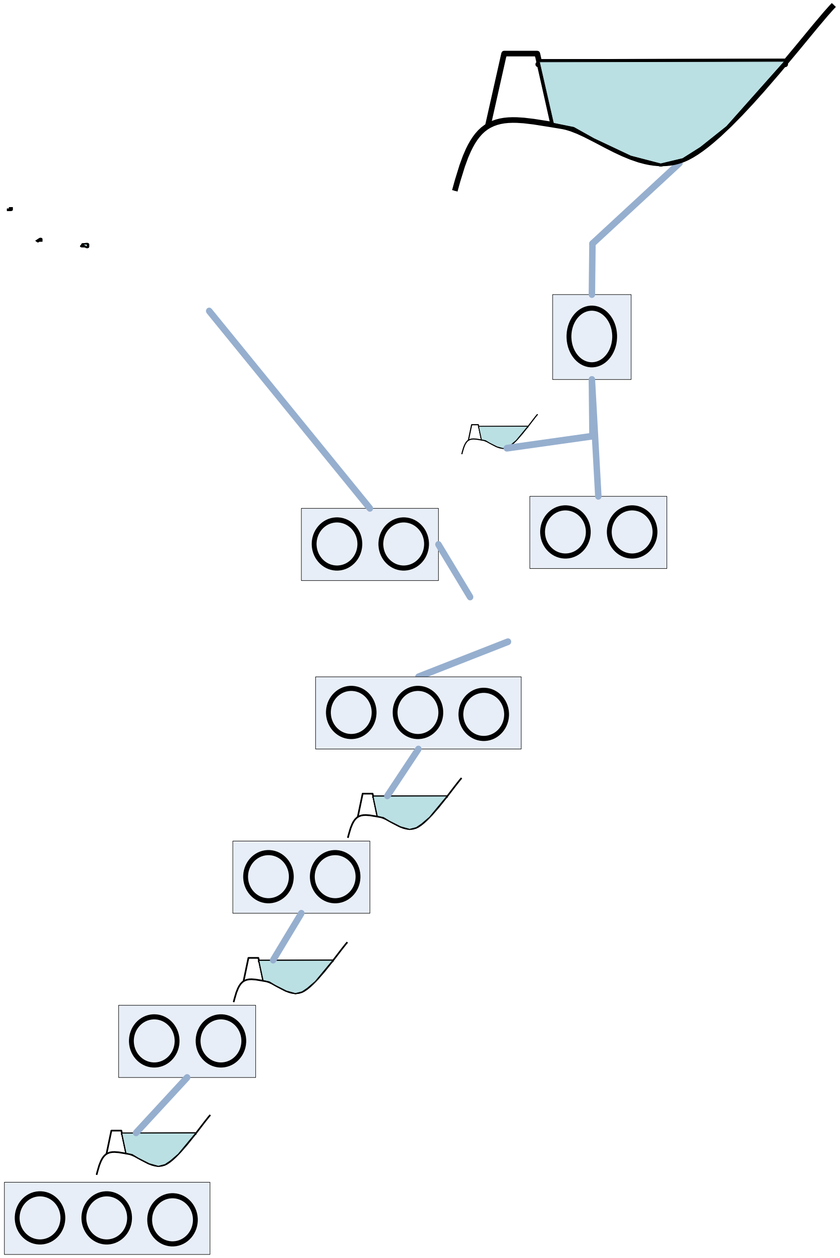




Results from a test on a real system

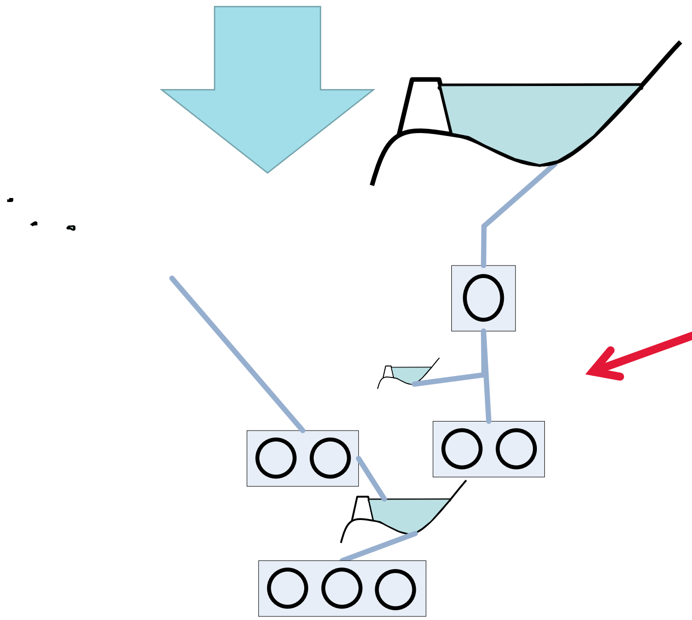
- Hourly time resolution
- Water value function with 100 steps
- 5 individual series of stochastic inflow
- Increasing trend in price, generate later in the optimization period if possible.

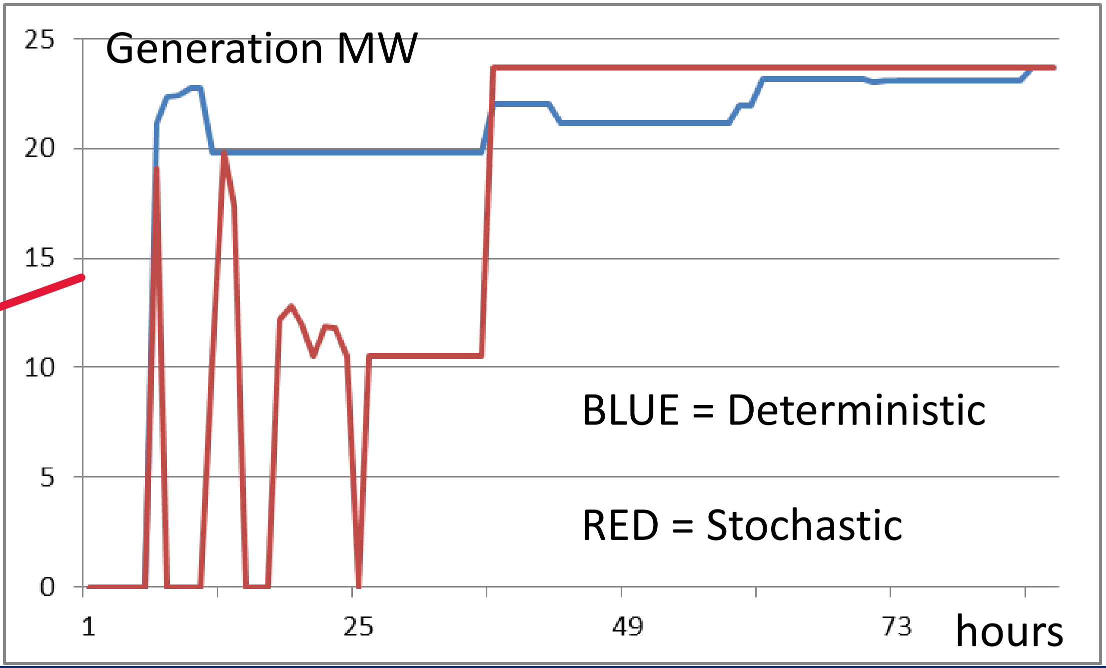




Results from the case

Case	Δ economy (%)	Comment
High overflow costs	+4	High cost and flexibility for action
Low overflow costs	+0.06	Indifferent
Doubled turbine capacity	+0.001	Indifferent



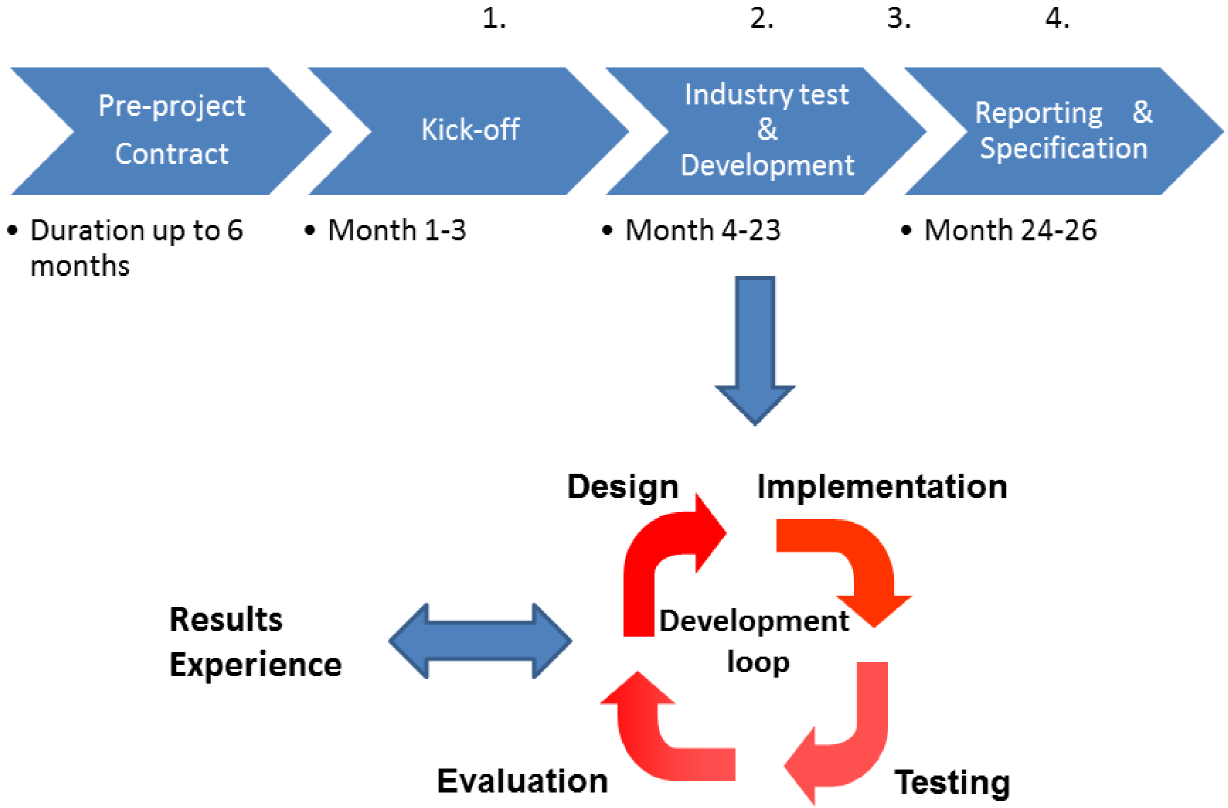


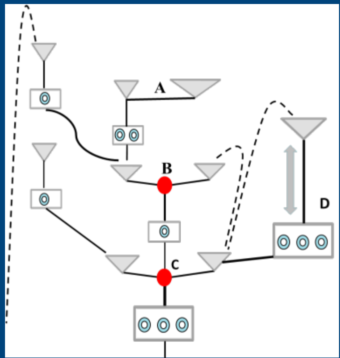
Rounding off the SHARM project

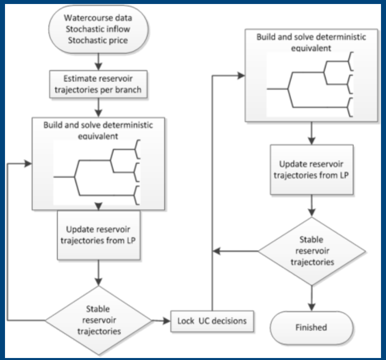
- Implemented a test interface and performed a industry test in the consortium utilities. This initial test failed to be conclusive whether or not implementation of the SHARM prototype in the utilities has positive economic value.
- Some reasons for this can be:
  - Difficulties to setting up and testing SHARM due to large data volumes on input and output from the model.
  - Currently available tools for especially inflow fails to represent realistic uncertainty.
  - So far we have tested existing water courses with the conditions of today regarding prices and inflow.
- Robustness of the results has improved with the SHARM model as the above results indicated. This is a common experience for the people that has performed the testing so far.

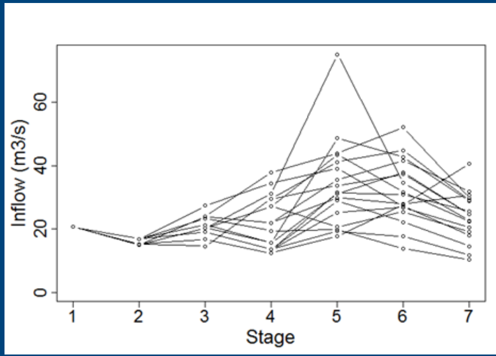
Veien videre

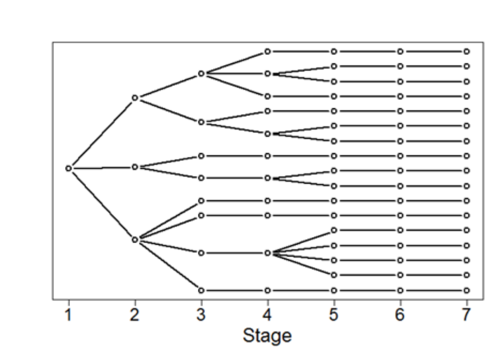
- The consortium behind SHARM has received additions fonding in a follow-up IPN project headed by Statkraft for further testing and improvement of the SHARM concept.











Takk for oppmerksomheten

NTNU
Department of Electrical Power Engineering

TrønderEnergi

ECO

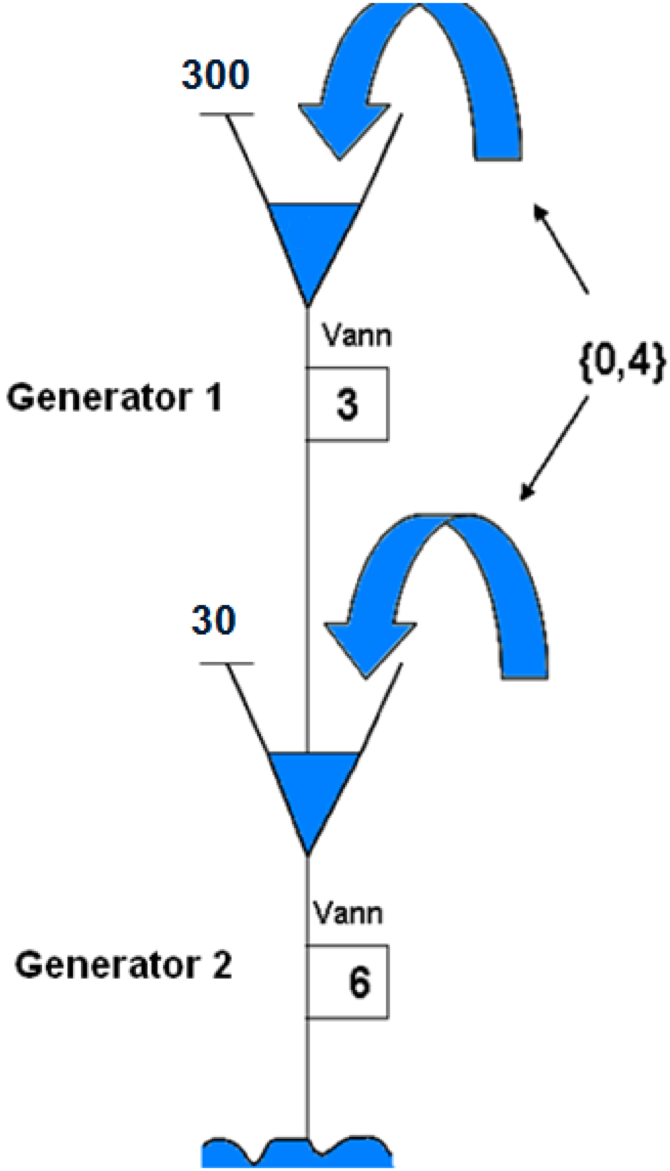
Statkraft

agder energi produksjon

HYDRO

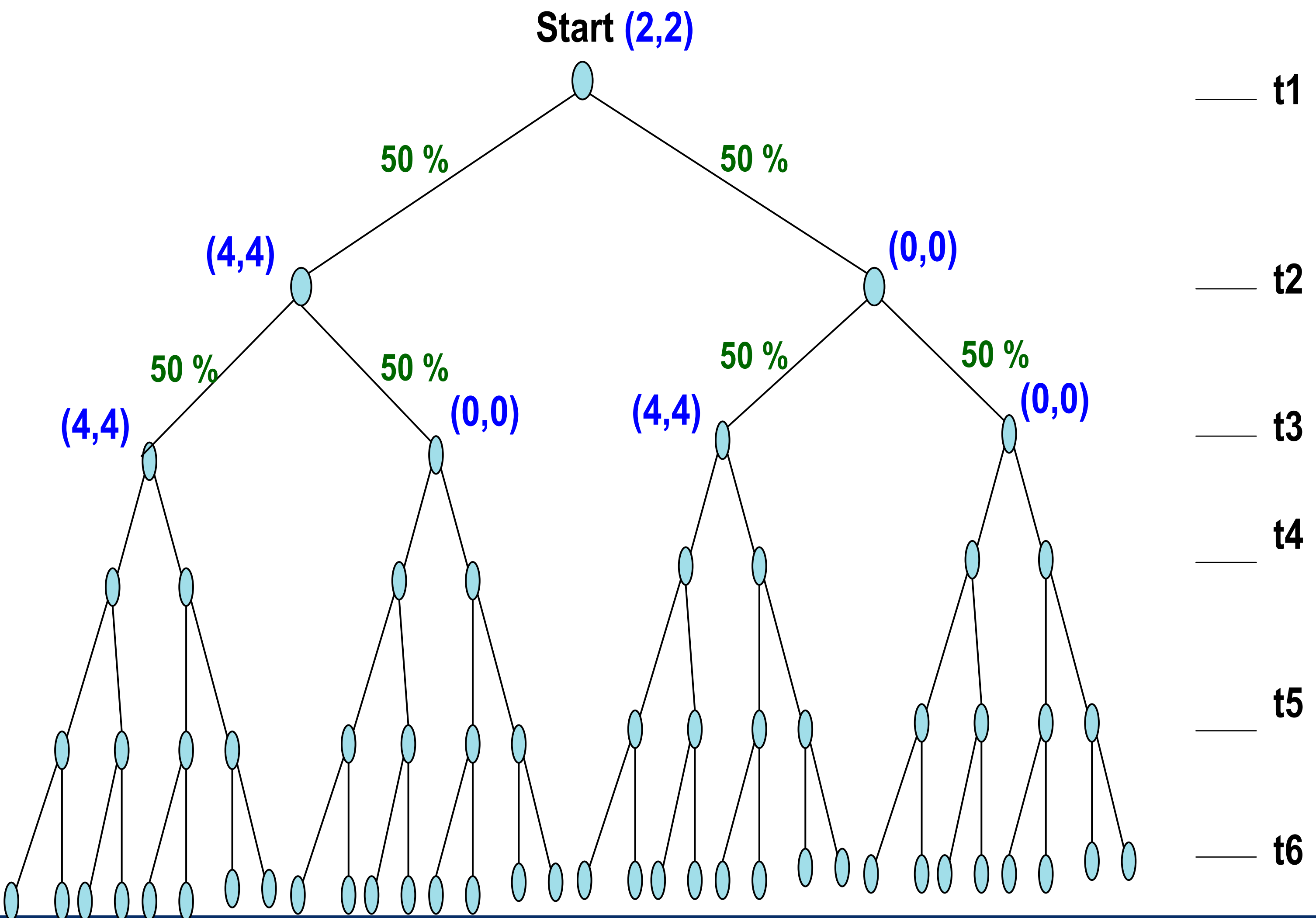
Extra slides

Produksjonssystemet – i konsept testen

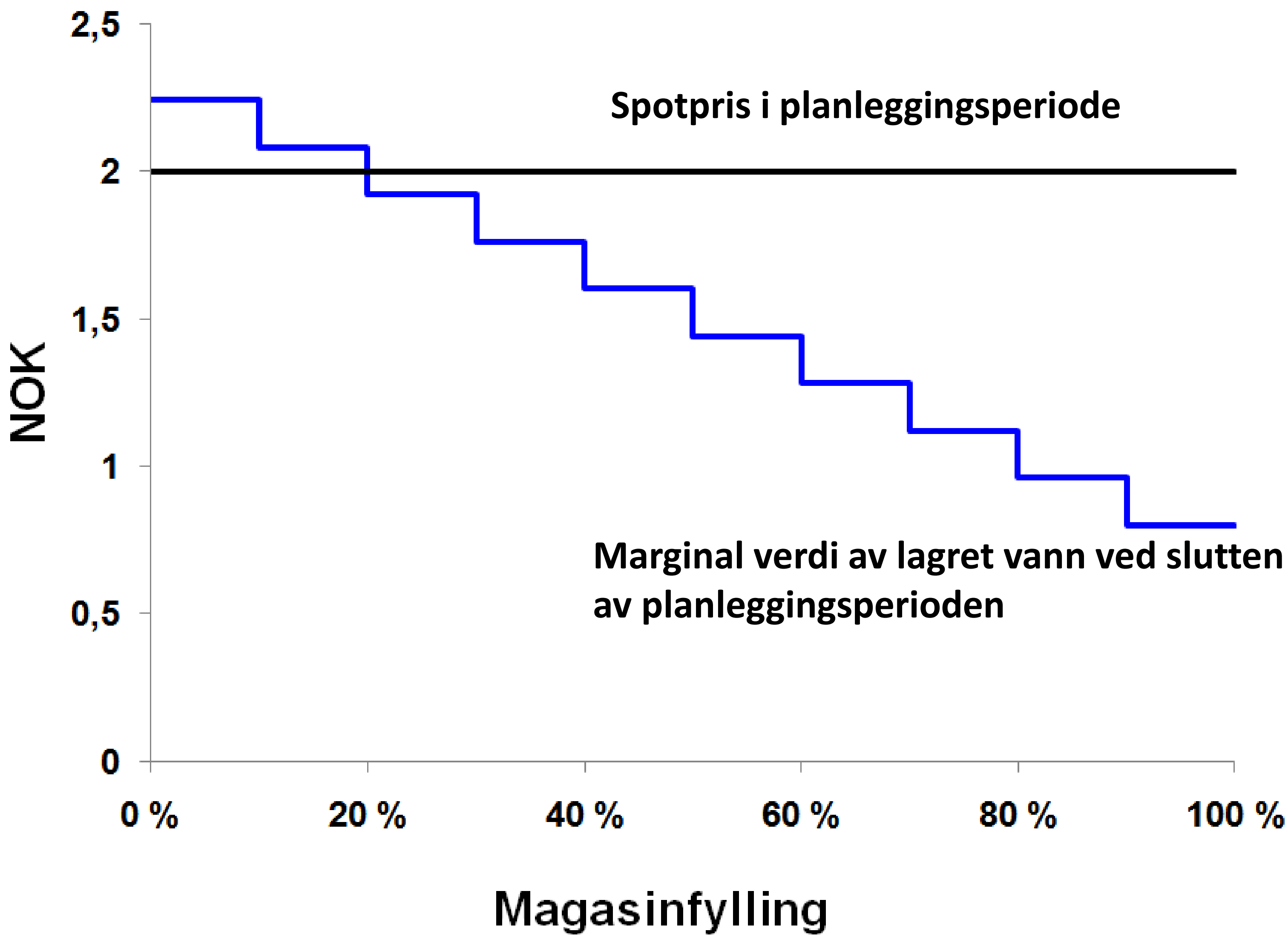


- Virkningsgrader
  - < 80 % av kapasitet : 1.0
  - > 80 % av kapasitet : 0.8
- Fallhøydekorreksjon
  - Fullt magasin: 1.0 / 0.1
  - Tomt magasin: 0.9 / 0.06

Perioder og usikkerhet i tilsig i konsept testen

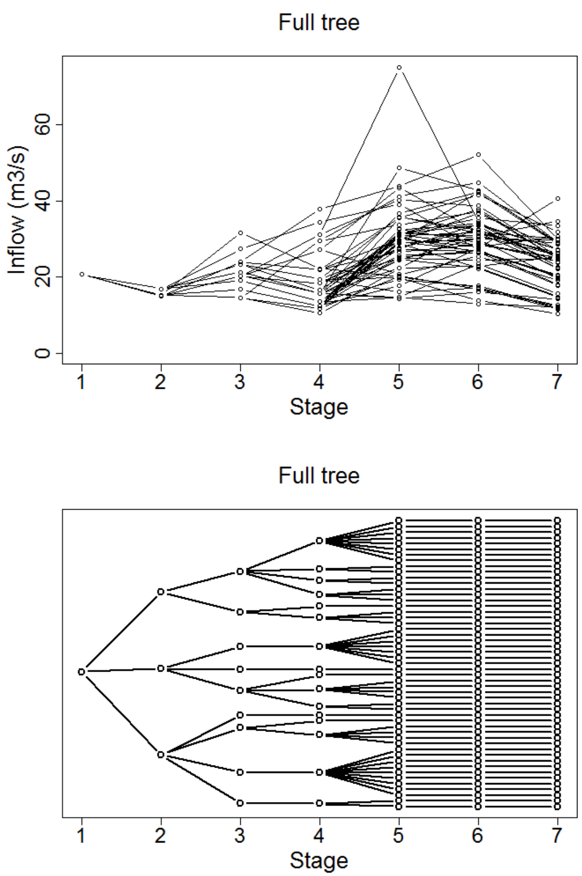


Økonomiske parametre i konsept testen

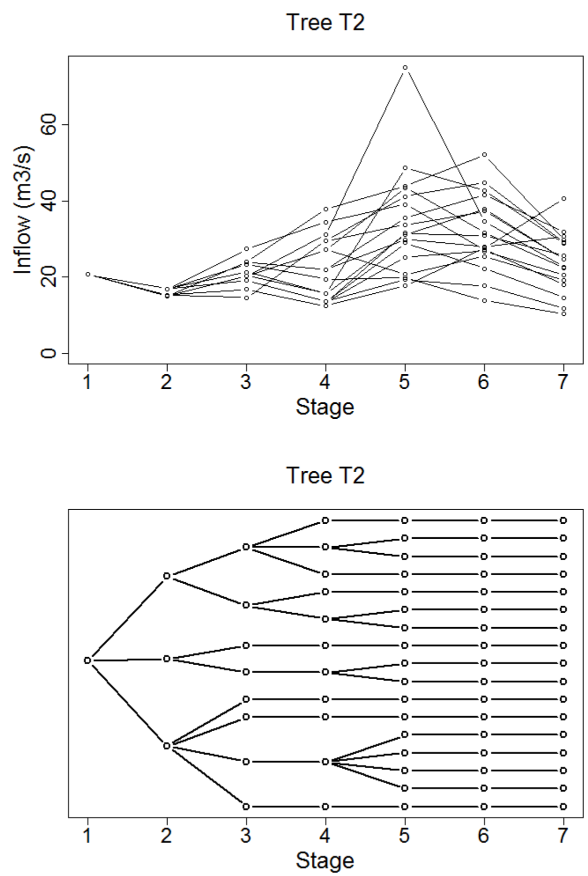


Results: Tree generation and reduction

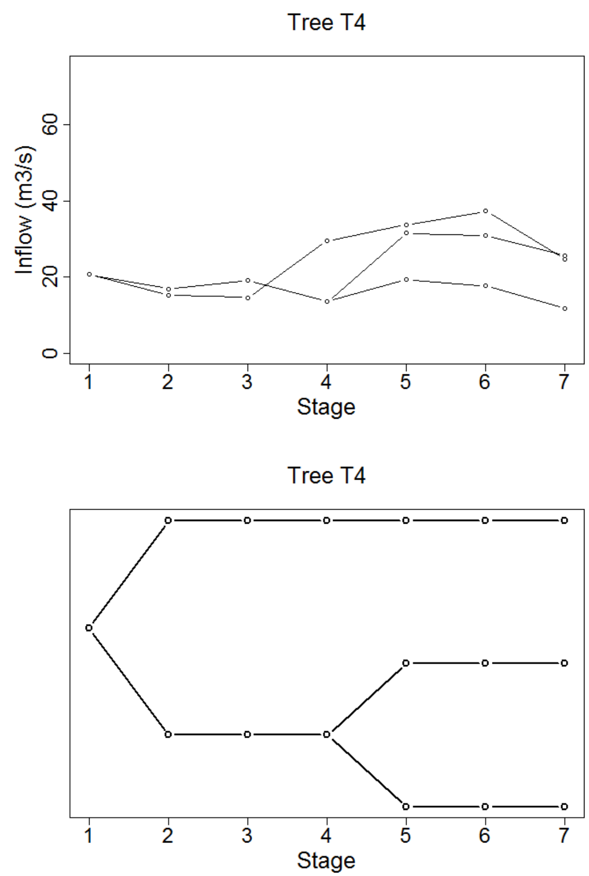
Reference tree



Reduced tree



Reduced tree



Bakteppe for å lykkes

- ENERGI21 – programmet
  - Balansekraft som 1 av 6 satsninger

- RENERGI som har sponset utv
en stokastisk korttidsmodell

Motivasjon (2)

- RENERGI – programmet
  - Balansekraft
- EnergiX
  - Nevner spesielt vannkraftens rolle
  - Balansetjenester
  - Lagring