SINTEF
75 år

Negative market prices in LTM models

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Backgroud

- The numbers of hours with negative market prices are increasing
  - Increasing share of uncontrolled production
  - Feed in tariffs
- SINTEFs LTM model does not handle negative market prices
  - Market models EMPS, FanSi ..
  - Local planning models; ProdRisk , seasonal models
- Wind power, solar power enters the power balance directly
- Hydro has no production costs
- My presentation
  - Why
  - What have we done to investigate the problem
  - Recommendations

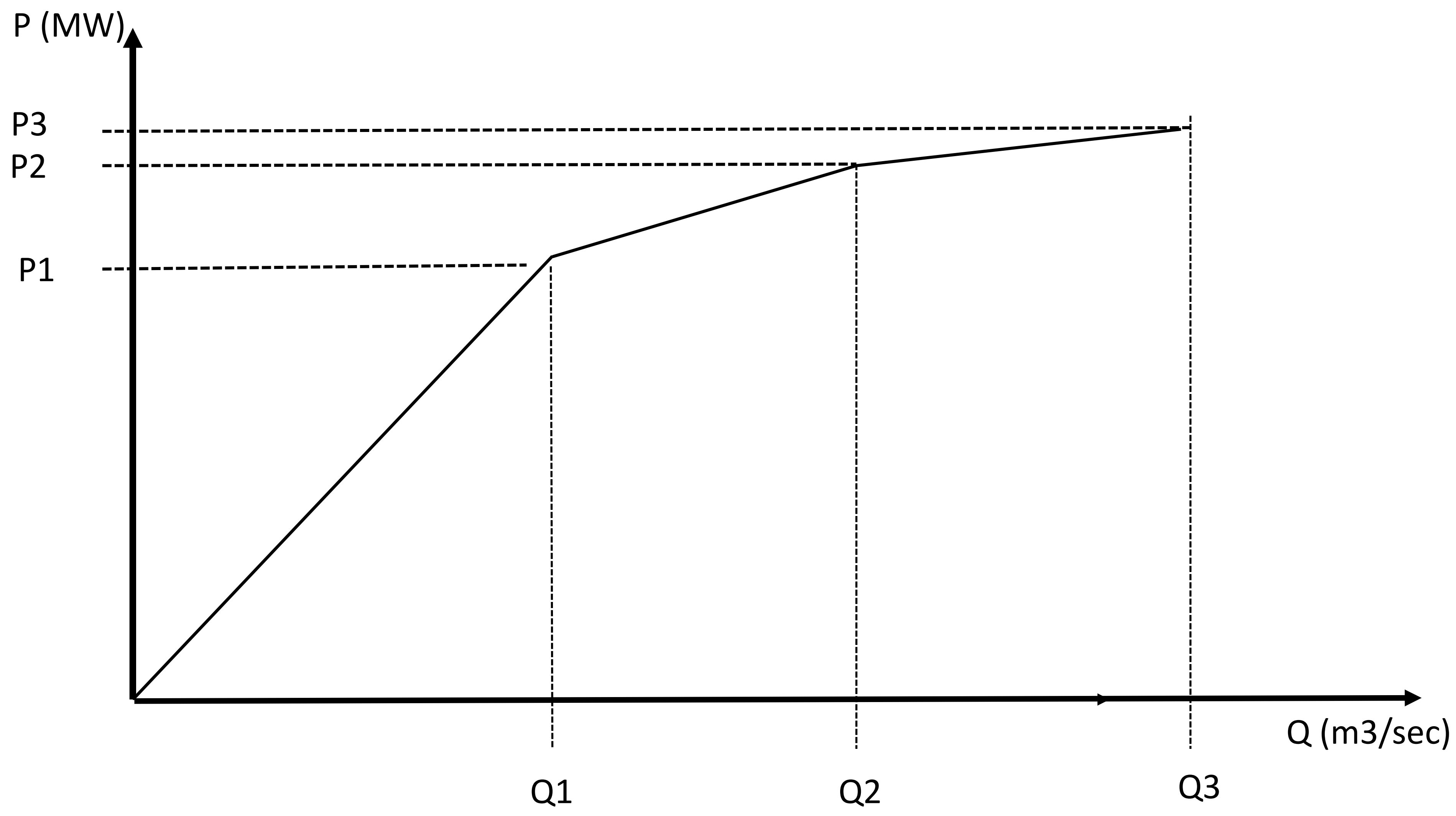
Why negative prices are not allowed in LTM models

- PQ description
  - Used in physical description of hydro units (ProdRisk, Seasonal model, FanSi, ngLtm)
  - Used to describe detailed hydro properties for aggregated model in EMPS.

- Transmission losses
  - Increased transmission to get rid of surplus power
  - Hydrogen – Can use transmission losses to represent a hydrogen market/storage

- Other unknown consequences with many complicated constraints?

Ordering of PQ segments



Current “handling” of negative prices in LTM models

- EMPS: A dump load with a very small positive price and large enough capacity ensures that calculated market prices always will be positive.

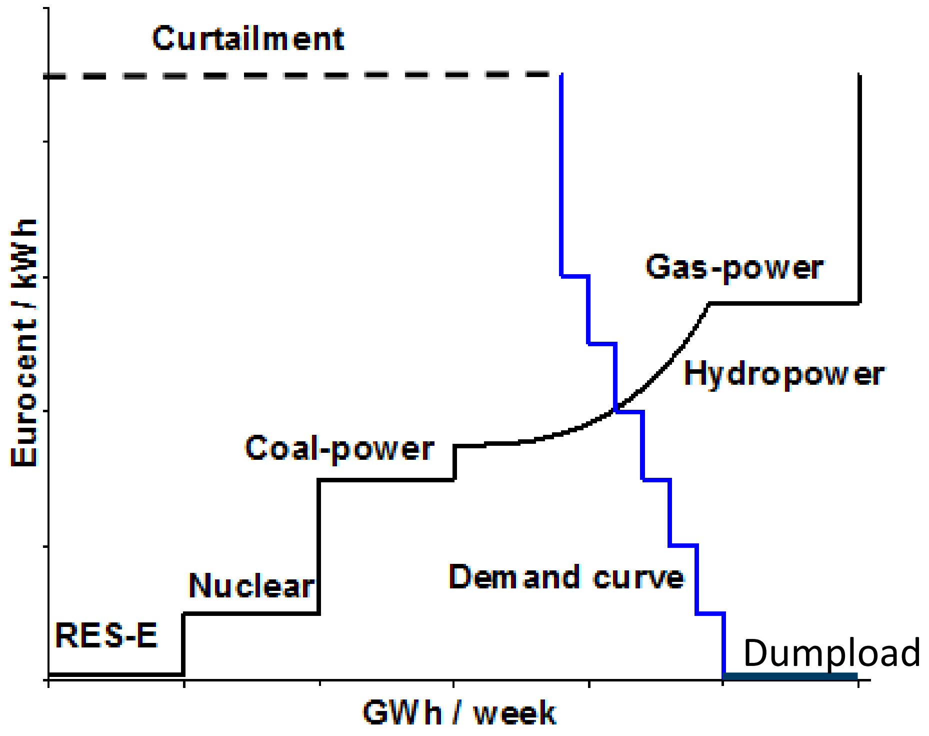
  The model cannot forecast negative prices

- ProdRisk: Negative input market prices will be automatically set to zero

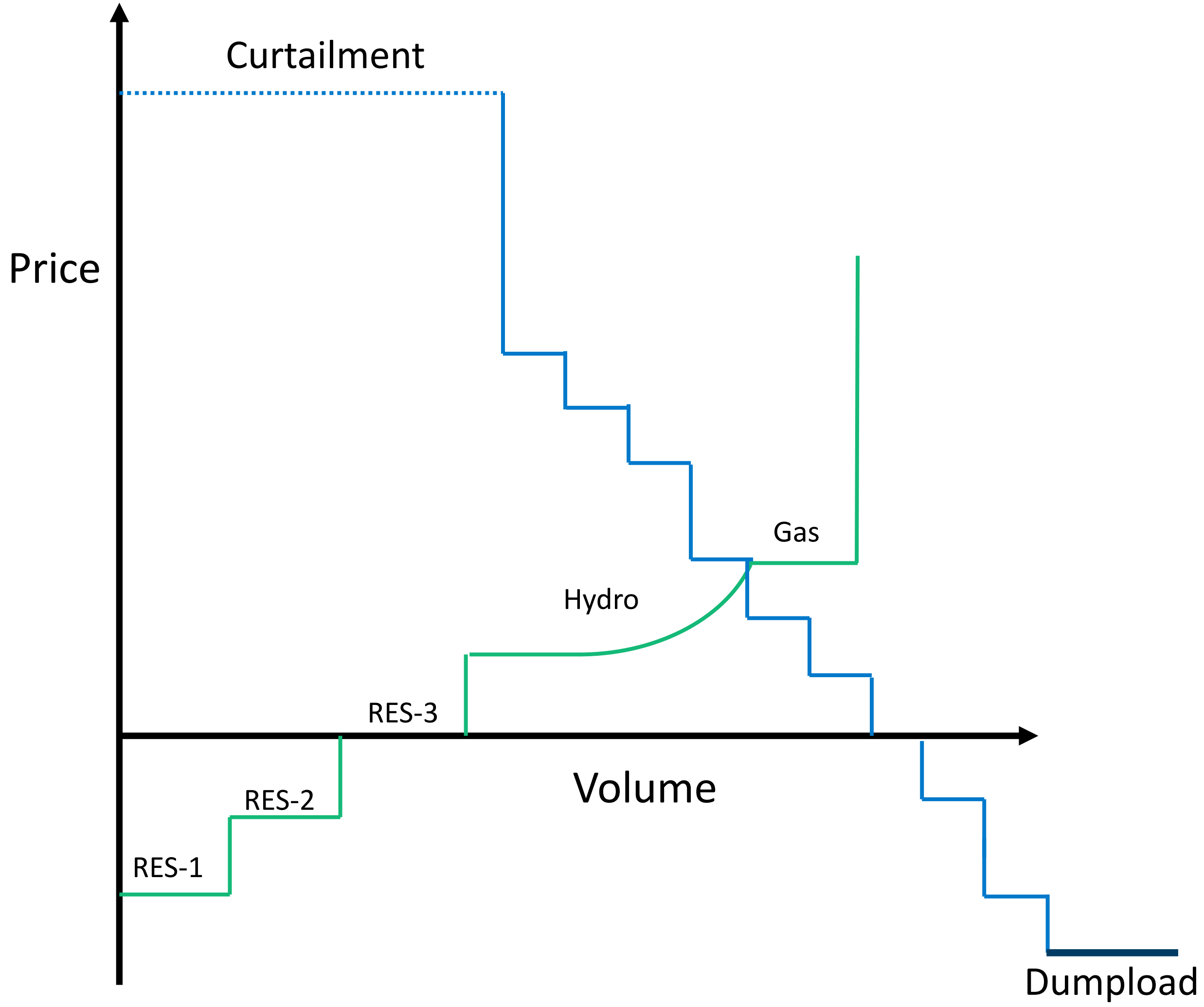
  Investment in pumping that benefit from negative prices cannot be correctly evaluated.

Modelling negative prices in a fundamental market model

Existing



With negative prices



Methods to handle negative prices in LTM

- None of these methods are perfect

- 1. Shift all input prices to the model upward corresponding to the lowest negative input prices.
  - Shift model results downward. (prices and water values)
  - Easiest to do if all input/output are handled automatically, e.g. using an API
- 2. Allow the model to handle negative prises – disregard wrong loading of PQ segments and other "unknown" consequences
  - In some models (Prodrisk, FanSi, ngLTM) simplify model description when prices are/becomes negative.
  - Iterations

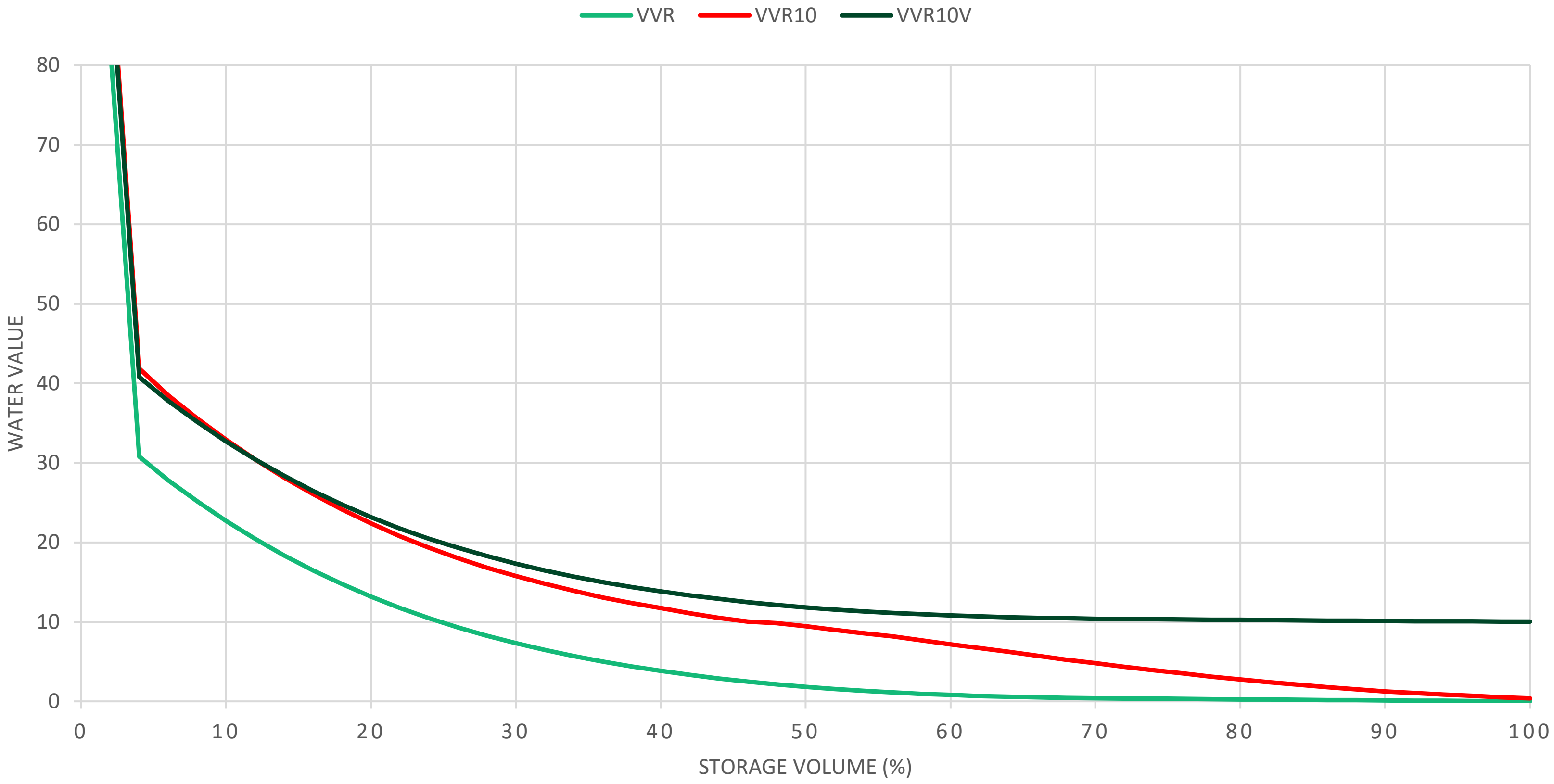
EMPS
1. Shift all prices upward

Teknologi for et bedre samfunn

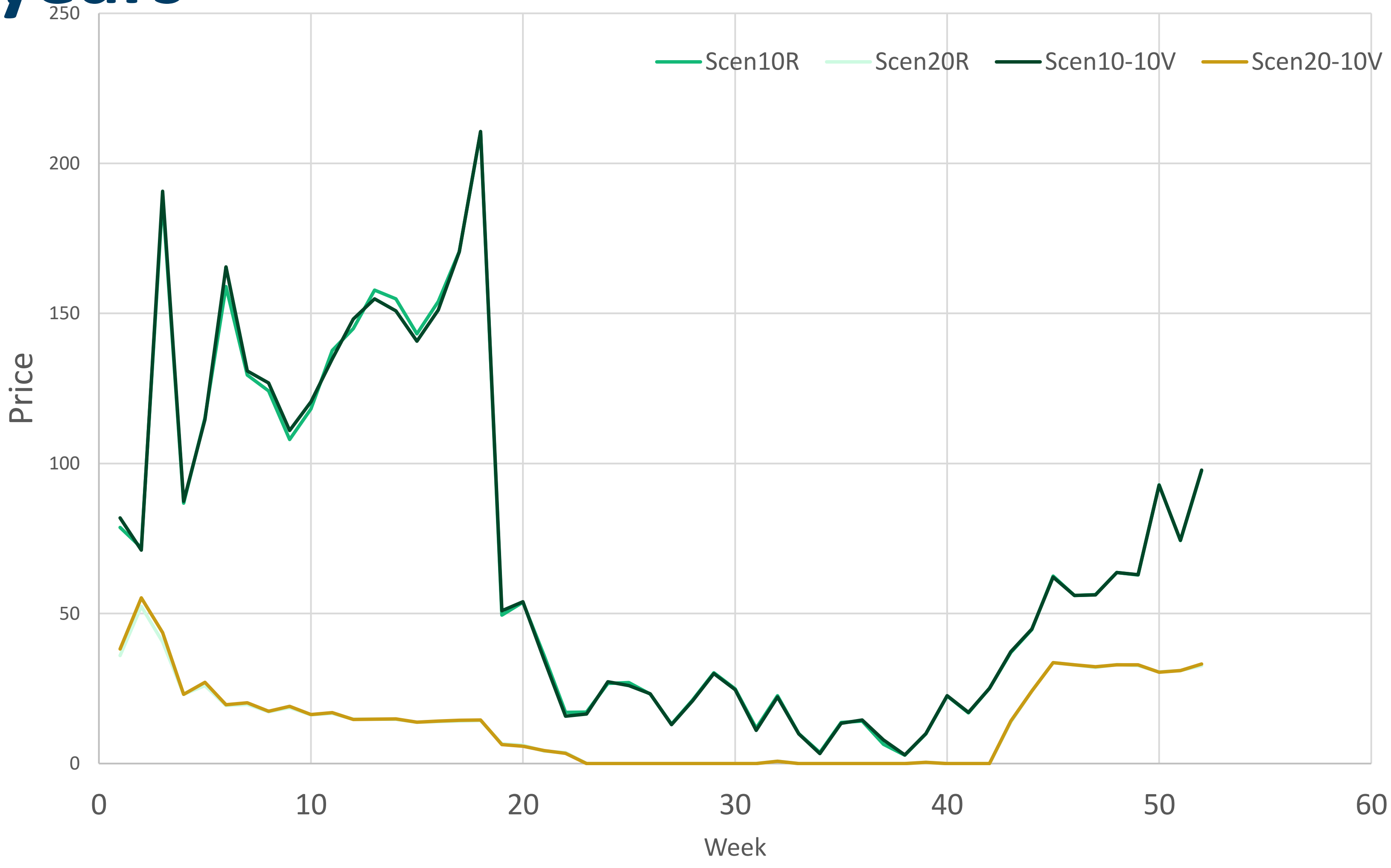
Test dataset

- 4 area test dataset
  - Serial simulation
  - 56 time periods within the week
- Case
  - Reference (R)
  - Reference with all prices shifted upward with +10 (R10)
  - Reference with all prices shifted upward with and run with a modified version of Vansim (R10V)
    - Prices if overflow is hard coded to 0.0 in standard version, should be 10 in shifted version.
- Results
    - Production /reservoirs operation
    - Water values
    - Simulated market prices after shifting back.

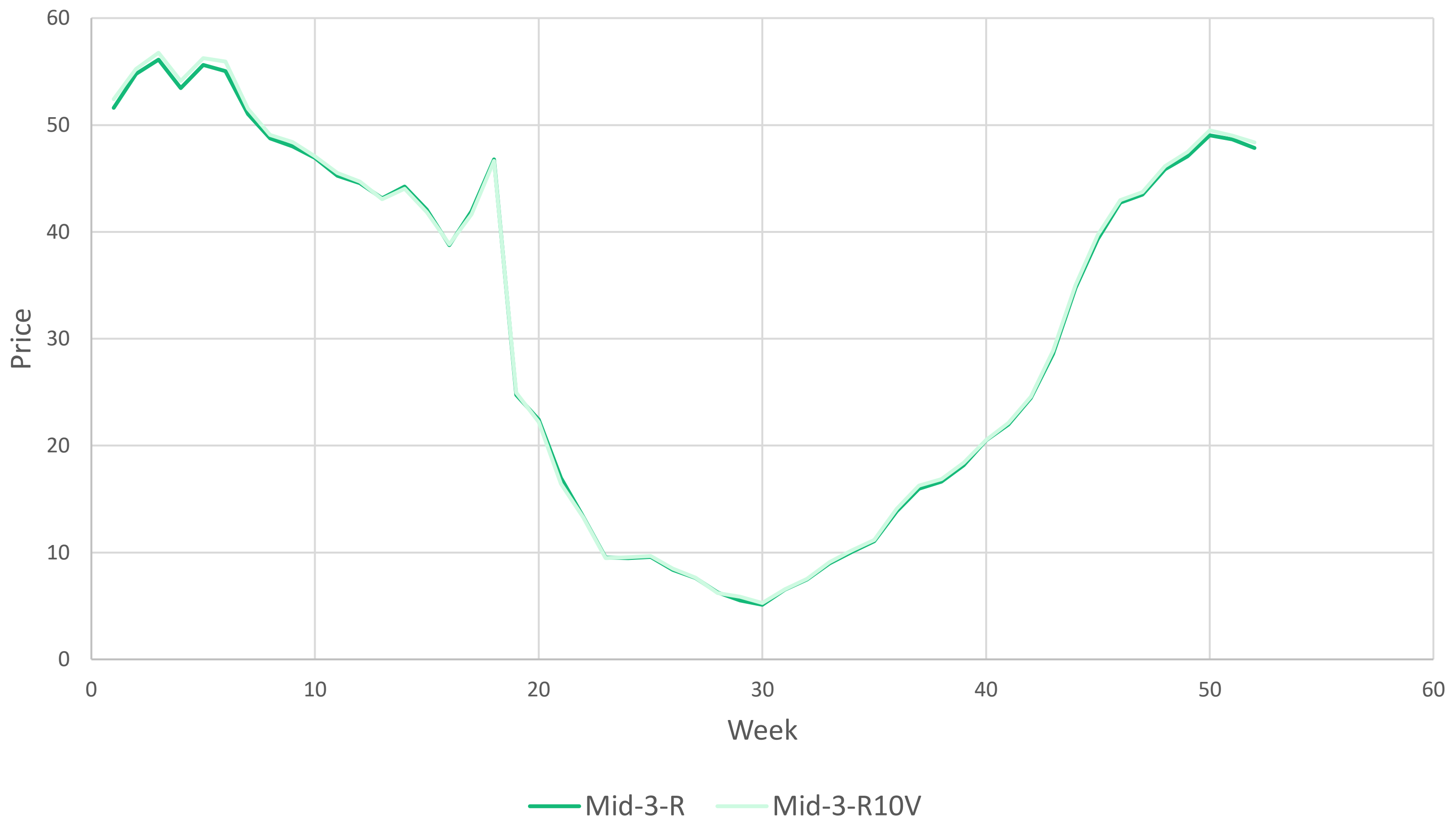
Water values week 18 in Numedal



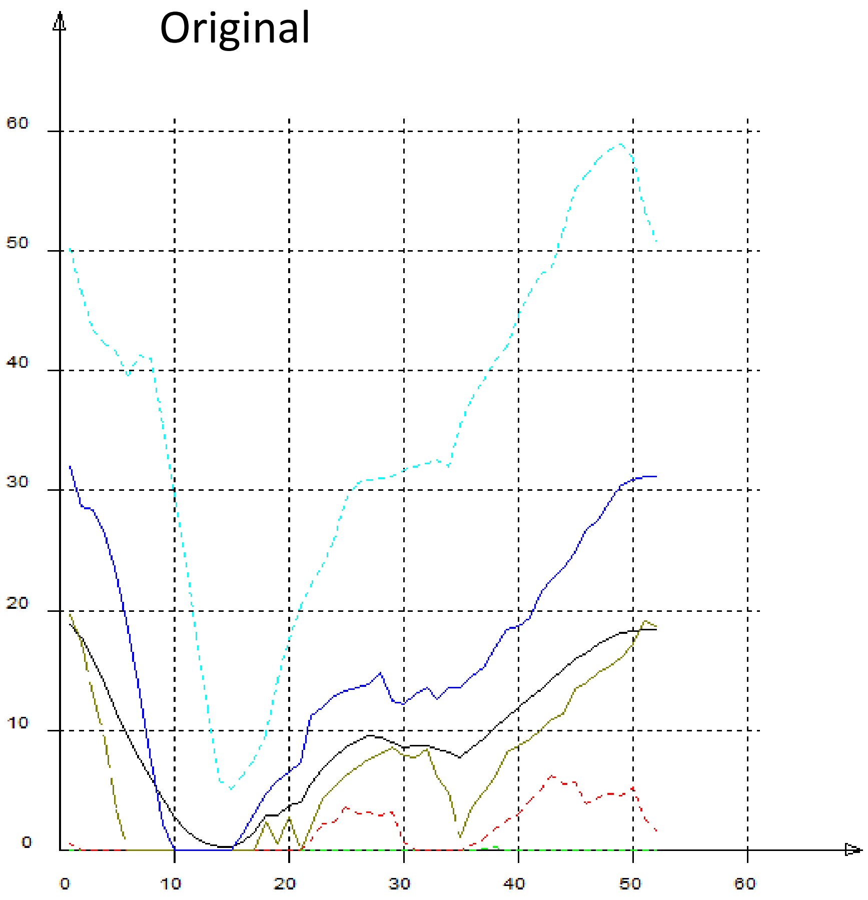
Simulated prices Otra for two different inflow years

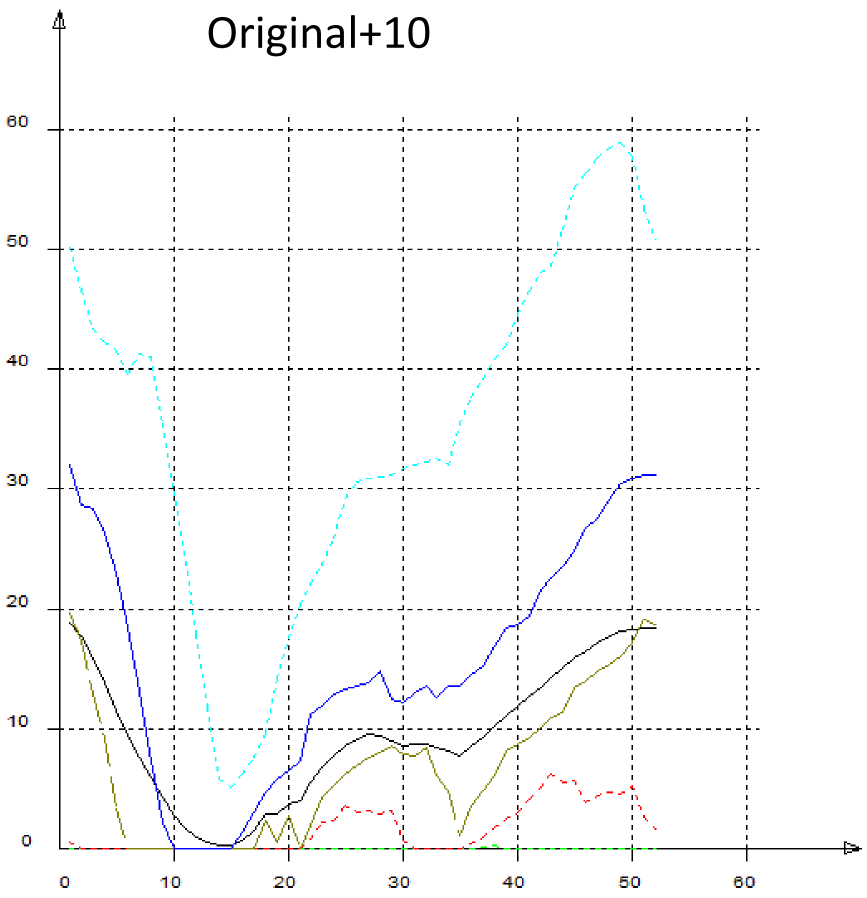


Average prices



Percentiles for reservoir Hovatn (Otra)





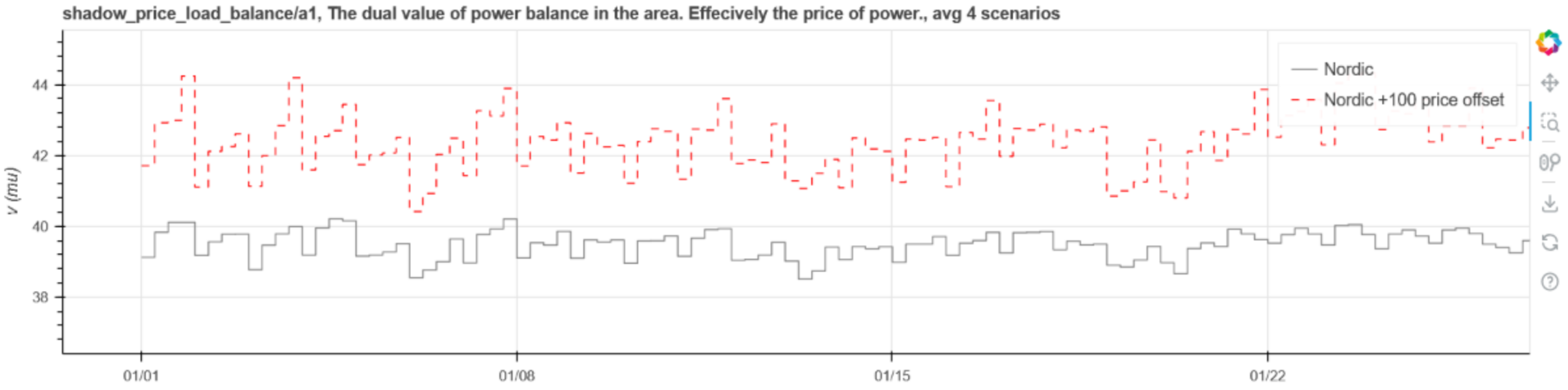
EMPS summary

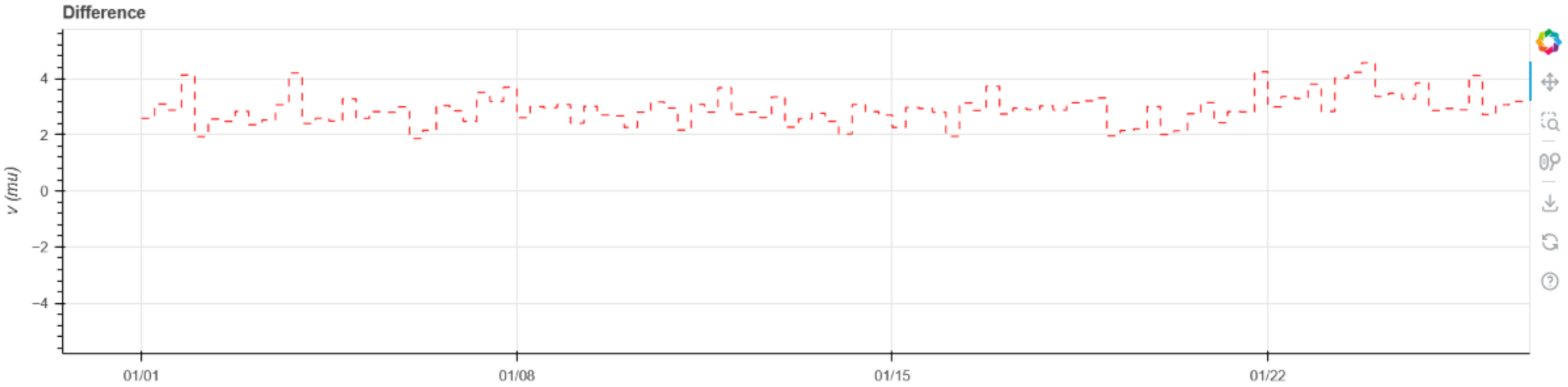
- Shifting prices upward seems to work
  - Should include a minor change in the water value calculations
- Simplifications
  - All uncontrolled production (wind, solar and hydro) goes directly to the power balance
  - Does not solve the real problem
- Improved solution –needs implementation
  - Possible to model thatat wind and solar (and hydro) has a production cost
  - Increased number variables and increased computation time

ngLTM
1. Shift all prices upward

Teknologi for et bedre samfunn

Comparing prices ngLTM –price shift +100





ngLTM-EMPS difference

- ngLTM –Physical hydro model
  - Penalties for violation of all constraints (Overflow, bypass, min reservoir levels, «buffer» reservoirs)
  - Quantified individual water values
- EMPS
  - No penalties in EMPS for handling of detailed hydro constraints.
  - Relative individual water values
- The size of the shift, compared to the market price, tested in ngLTM is much larger than for the EMPS test.

Recommendations

- ngLTM
  - Want to avoid iterative based solutions – because of computation time
  - Simulation
    - Allow for negative prices
    - Report production deviation
    - If negative prices , no transmission losses, ramping
  - Water values – needs further investigation

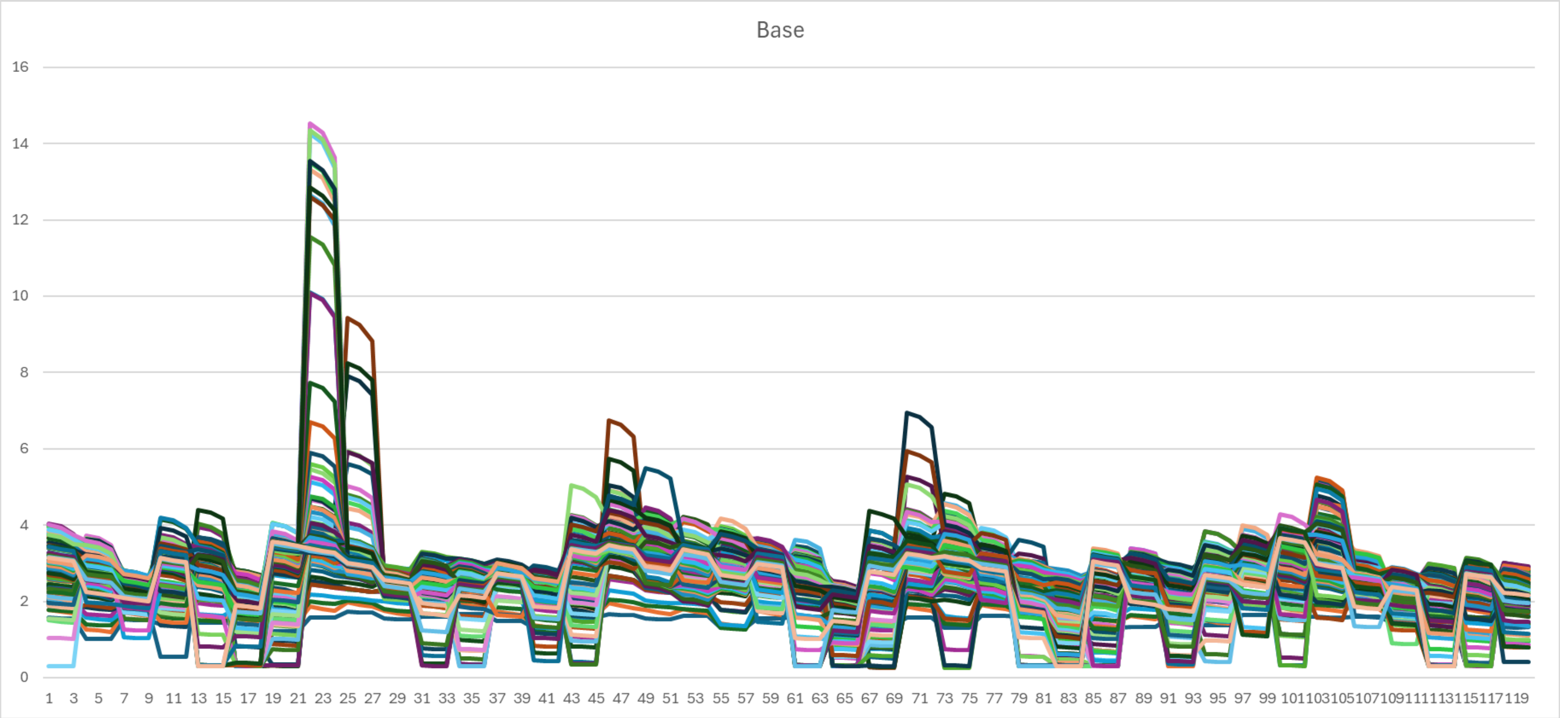
- EMPS
  - Use the price shifting method

ProdRisk

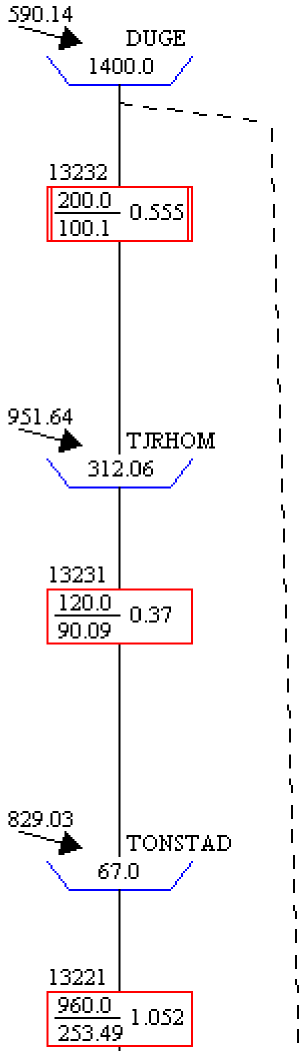
Teknologi for et bedre samfunn

Testing with different price input

- Base case prices as shown below
- All values adjusted upward +2.0 EUR/MWh
- Also done tests with shift downward 2.0 EUR/MWh
  - Slightly modified ProdRisk



Sira Kvina «snip», Shift prices upward



+ 2.0
Adjust penalties (-2) and endpoint water values (VVERD)

Prisrekke	K_KOST	Sluttmag (Mkr)
Base	-260.22	70.63
Pos2 (+2.00)	-430.62	120.73

```
Forste uke i sesongen ;    1;
Siste uke i sesongen ; 104;
Forventningsverdi objektfunksjon (kkr ; 184393.453;
Prisnivaa vannverdiene gjelder for |re/kWh;  1.445;
Modul nr;Magasin navn;Maksimalt magasinvolum (Mm3); Startmagasin (Mm3);Restm
13232;DUGE;  1400.000;  840.000;  1008.810;  2.626;  2.783;  5.166;  1.967;
13231;TJRHOM;  312.060;  187.236;  250.871;  2.563;  3.180;  3.602;  1.406;
13221;TONSTAD;  67.000;  40.200;  60.396;  2.350;  2.350;  2.456;  1.045;
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Forste uke i sesongen ;    1;
Siste uke i sesongen ; 104;
Forventningsverdi objektfunksjon (kkr ; 305764.656;
Prisnivaa vannverdiene gjelder for |re/kWh;  3.445;
Modul nr;Magasin navn;Maksimalt magasinvolum (Mm3); Startmagasin (Mm3);Restm
13232;DUGE;  1400.000;  840.000;  1021.456;  4.743;  5.050;  9.331;  1.967;
13231;TJRHOM;  312.060;  187.236;  257.327;  4.620;  5.060;  6.494;  1.406;
13221;TONSTAD;  67.000;  40.200;  62.142;  4.469;  4.469;  4.671;  1.045;
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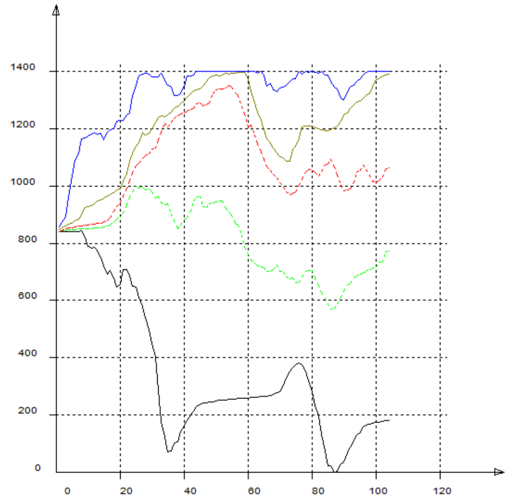
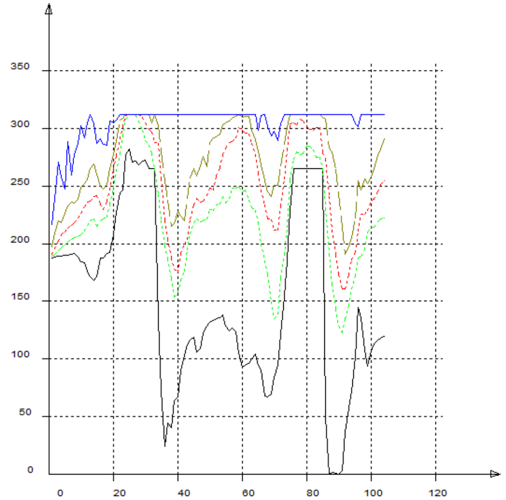
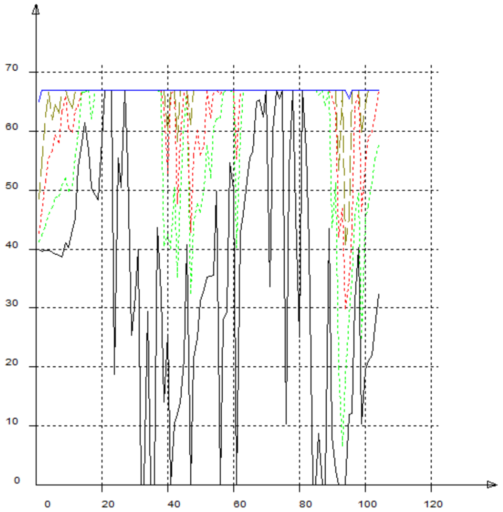
Reservoir

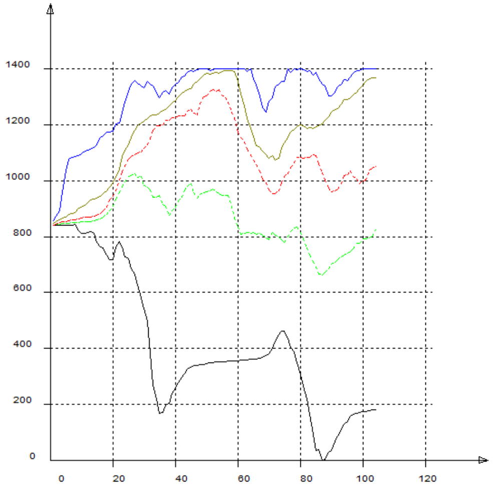
Duge Tjørhom Tonstad

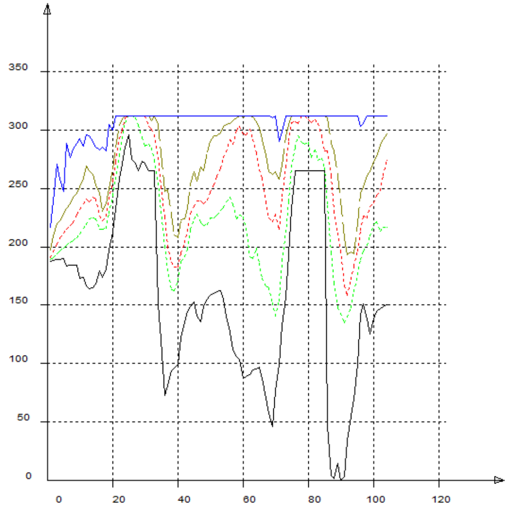


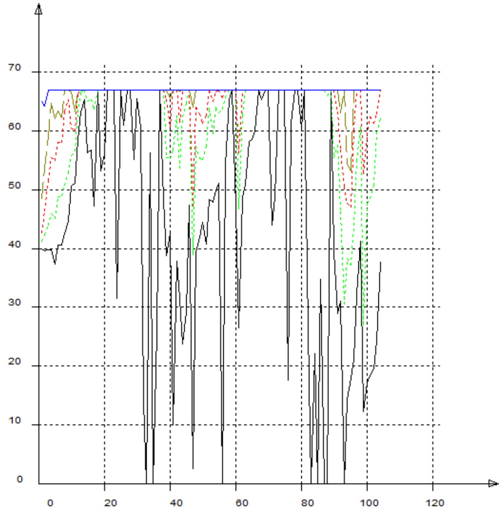




Base





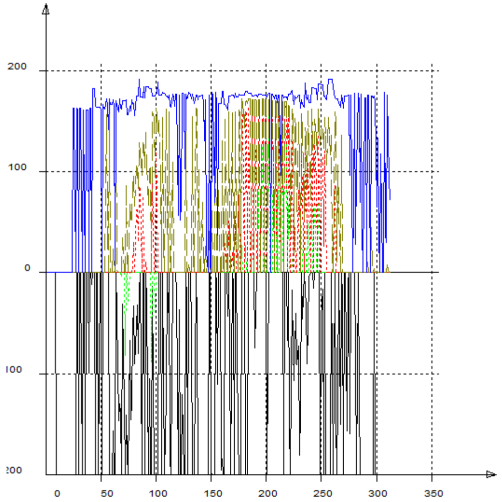


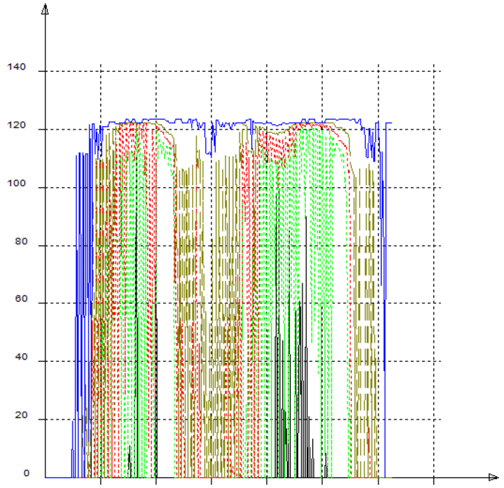
Pos2

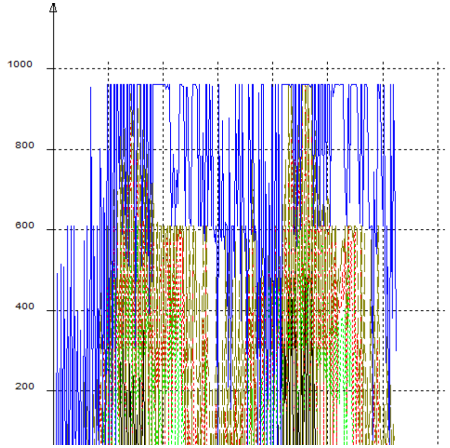
Production

Duge | Tjørhom | Tonstad

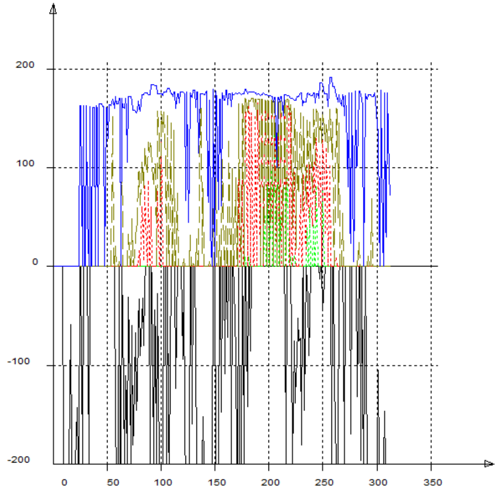
Base

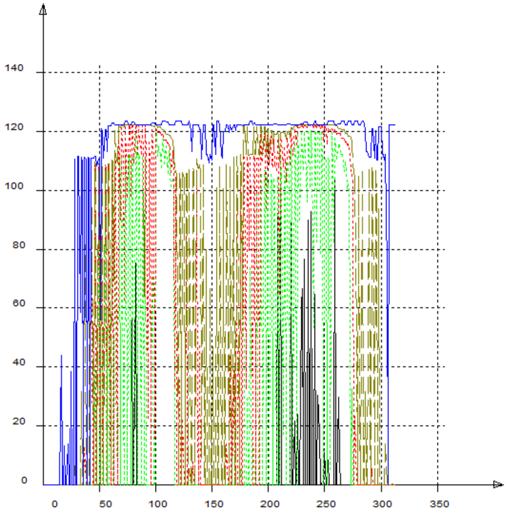


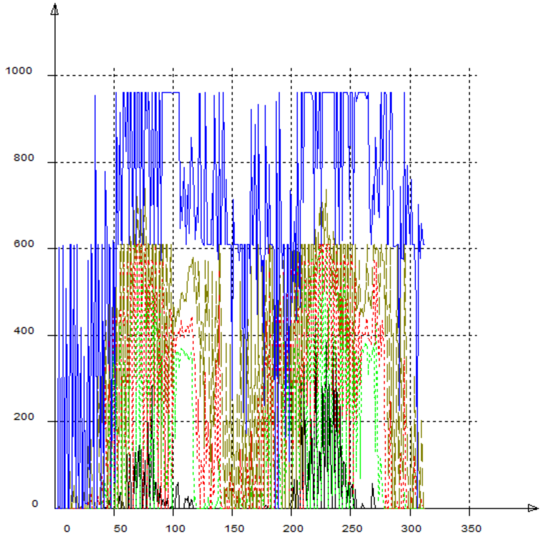




Pos2







Recommendations Prodrisk

- Shifting negative input prices upward works
  - Adjust dump load prices and overflow/bypass penalties
  - Result programs give wrong income, OK for comparison of cases
  - Difficult to use operationally with cut coupling to short-term model.

- Recommend solution – need some model development
  - Allow for negative input prices
  - Use constant hydro efficiency for stage problems with negative prices

75 år med teknologi for et bedre samfunn

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ProdRisk changes

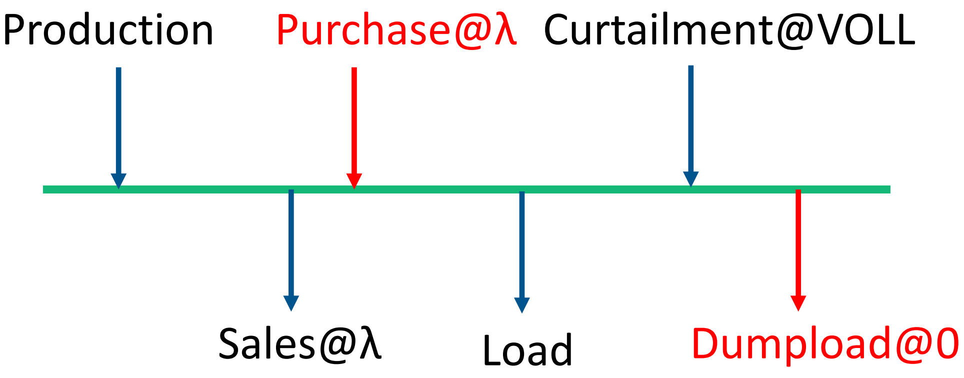
#1
Allow for negenative prices

Putt_pris.f:

```
ÍG  CŶRŖÍŞ  ĽŢ  . .  CŶRŖÍŞ   . .

íğ  ắđs ņắslřsîş íčỳţţ ířêņņ      .  ţḩêņ
    CŶRŖÍŞ   CŶRŖÍŞ DÍGAĶŢ
êľşê
    CŶRŖÍŞ     , . CŶRŖÍŞ DÍGAĶŢ
êņđîğ
```

Tiltak #2
Remove dumpload



Tiltak #3
Allow negative water values

prodrisk.CPAR | straff.CPAR

```
4,
'CFlomFram',2.0,'straff/energi',
'CFlomBak',2.0,'straff/energi',
'CForbFram',2.0,'straff/energi',
'CForbBak',2.0,'straff/energi',
```

#4 Adjust VVERD

- Adjust all water values