Evaluation of measures for hydropower flexibility reduction due to environmental constraints

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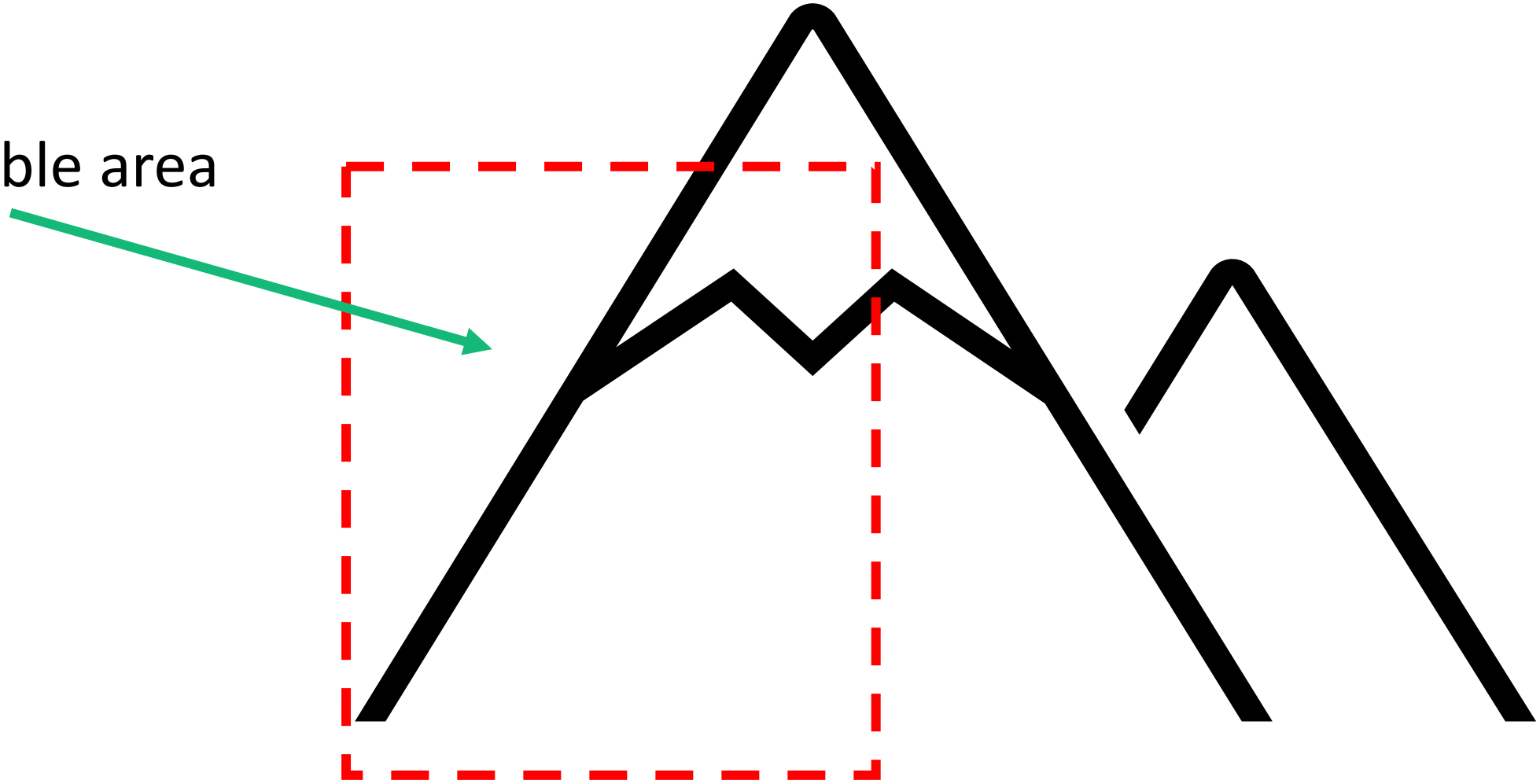
Minimum bypass

Minimum reservoir level

Minimum discharge

Feasible area



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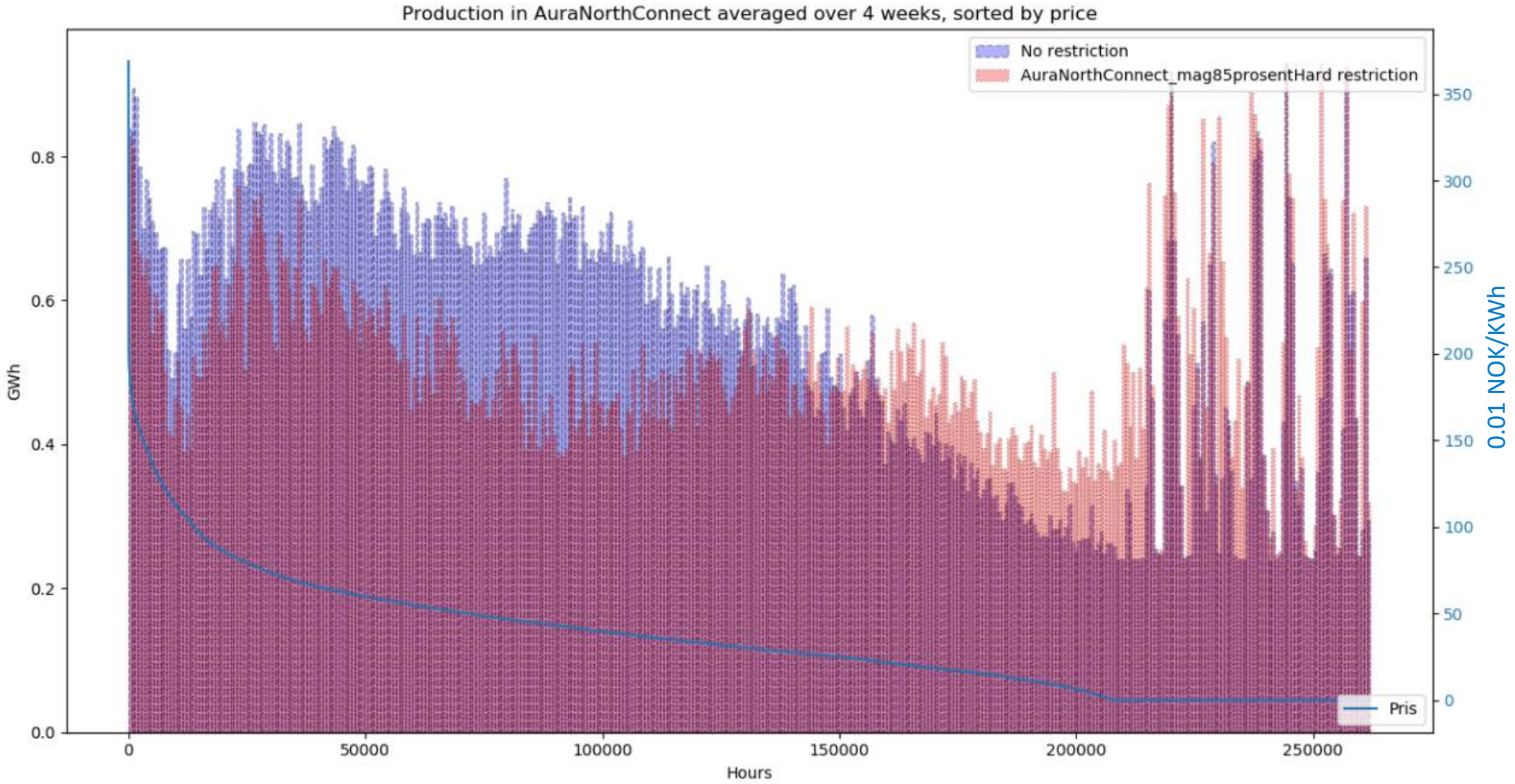
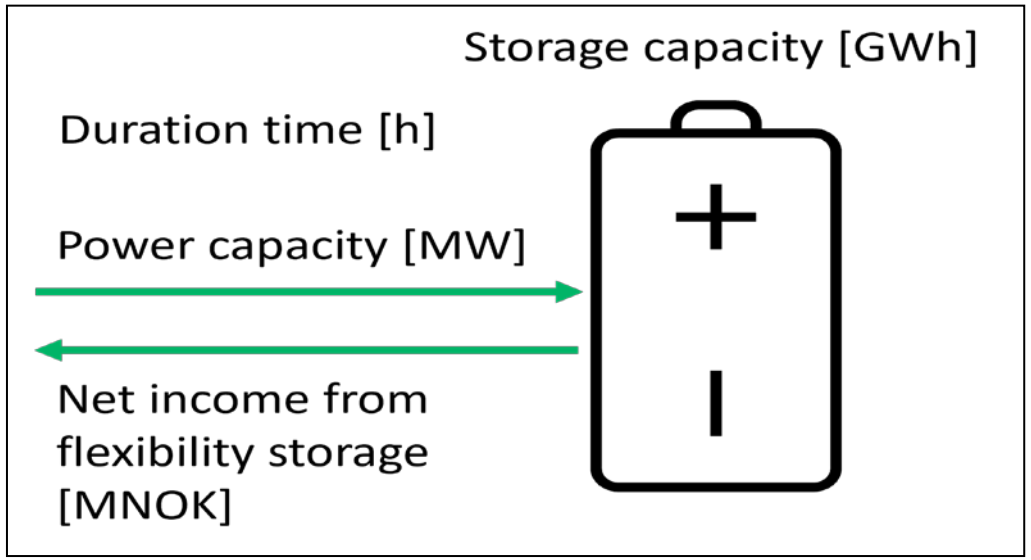

Production in AuraNorthConnect averaged over 4 weeks, sorted by price
No restriction
AuraNorthConnect_mag85prosentHard restriction
Pris
GWh
0.01 NOK/KWh
Hours
0.0
0.2
0.4
0.6
0.8
0
50000
100000
150000
200000
250000
0
50
100
150
200
250
300
350

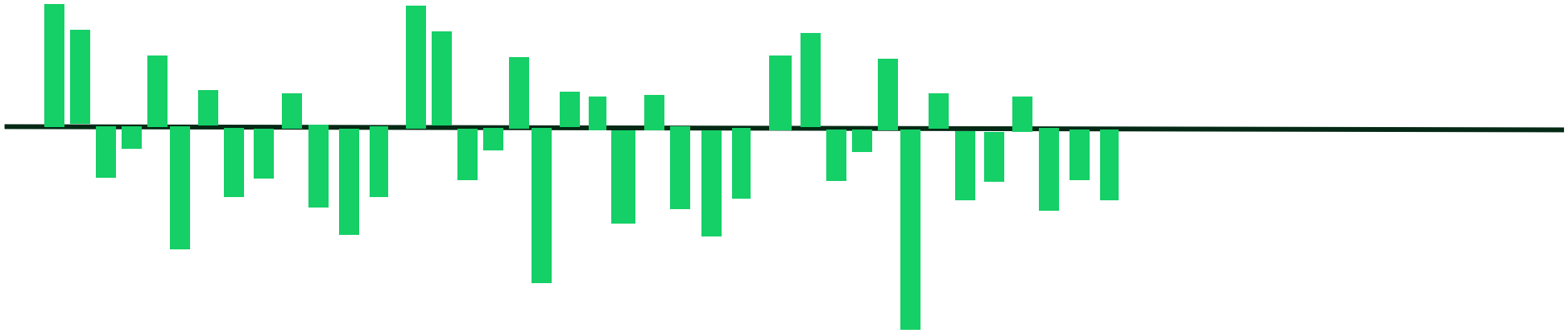
Measuring the impact of environmental constraints on hydropower flexibility

Equivalent energy storage



Flexibility factor

$$F = \frac{\pi^*}{\overline{\pi}}$$



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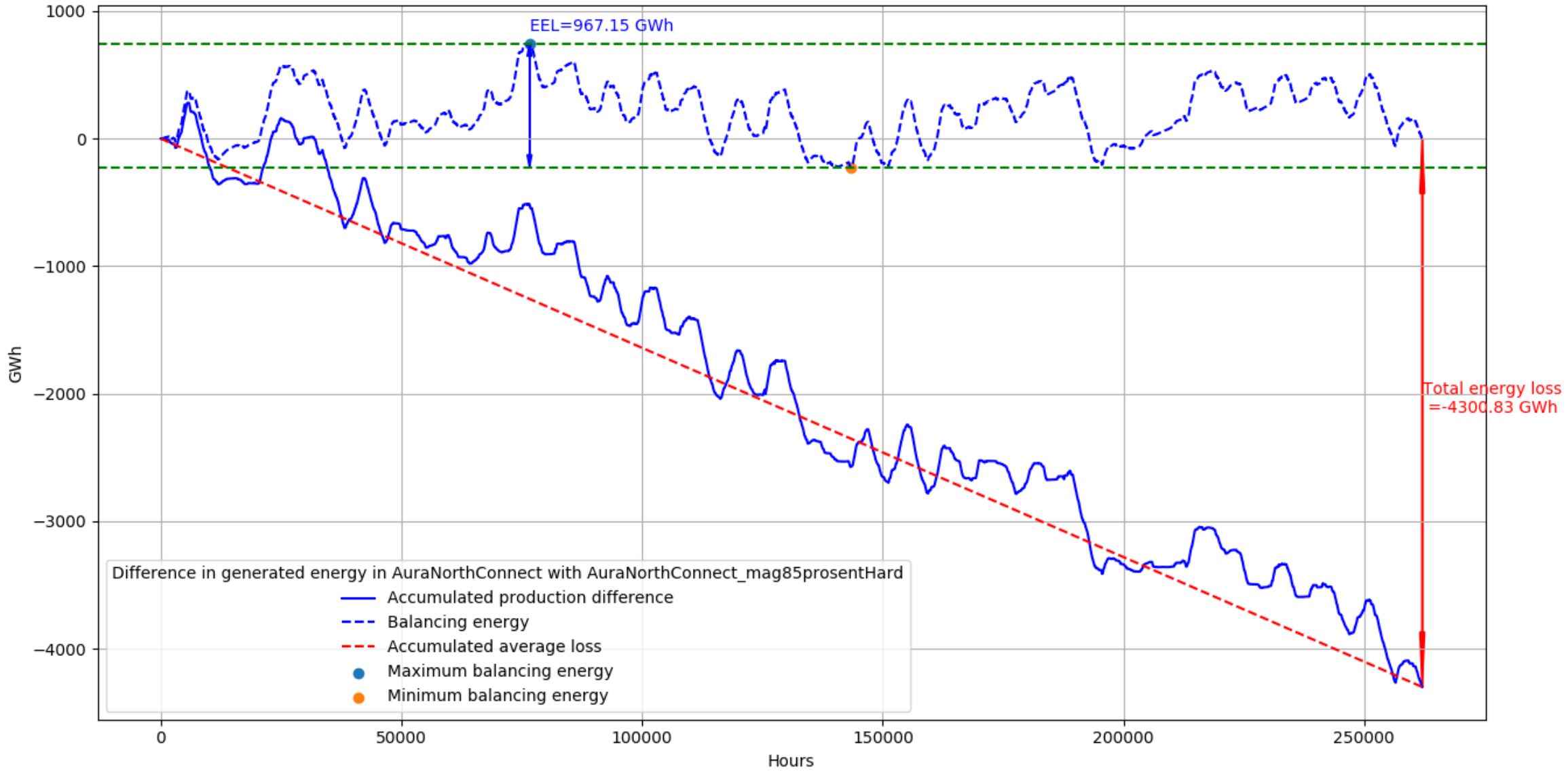
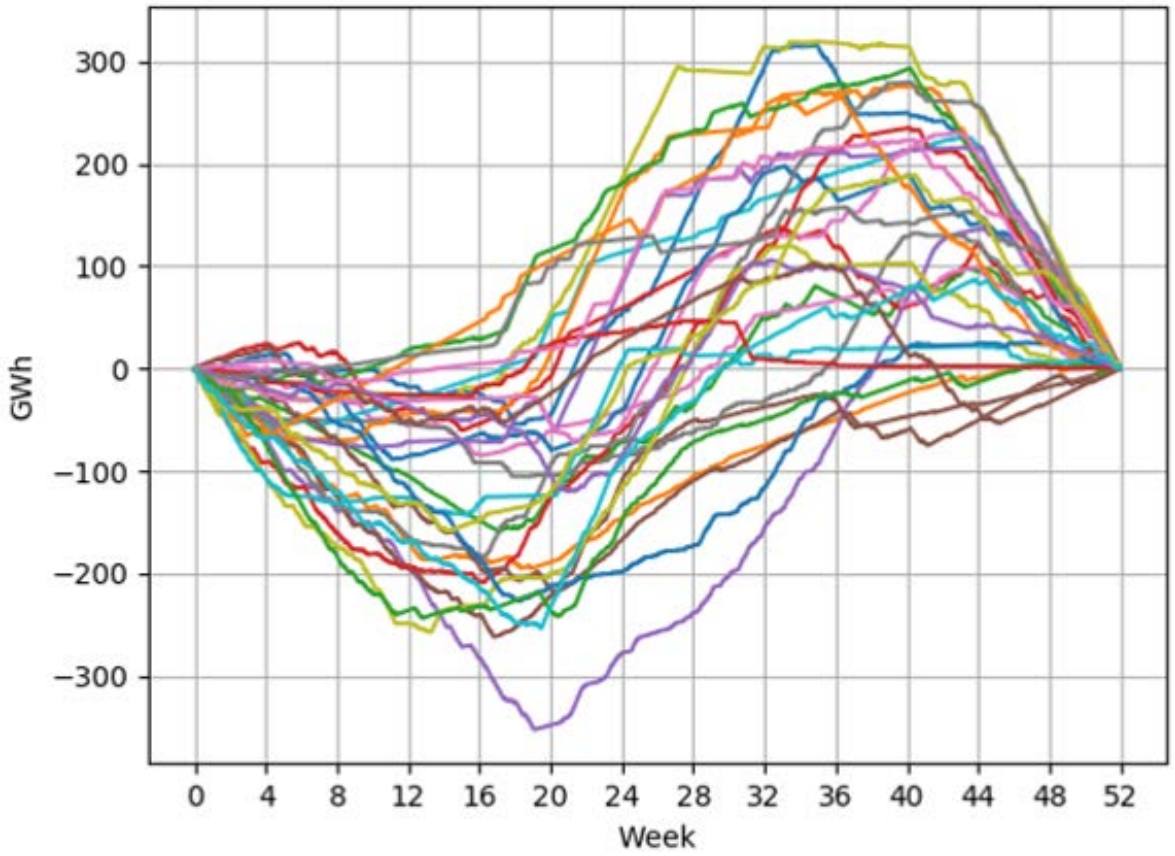
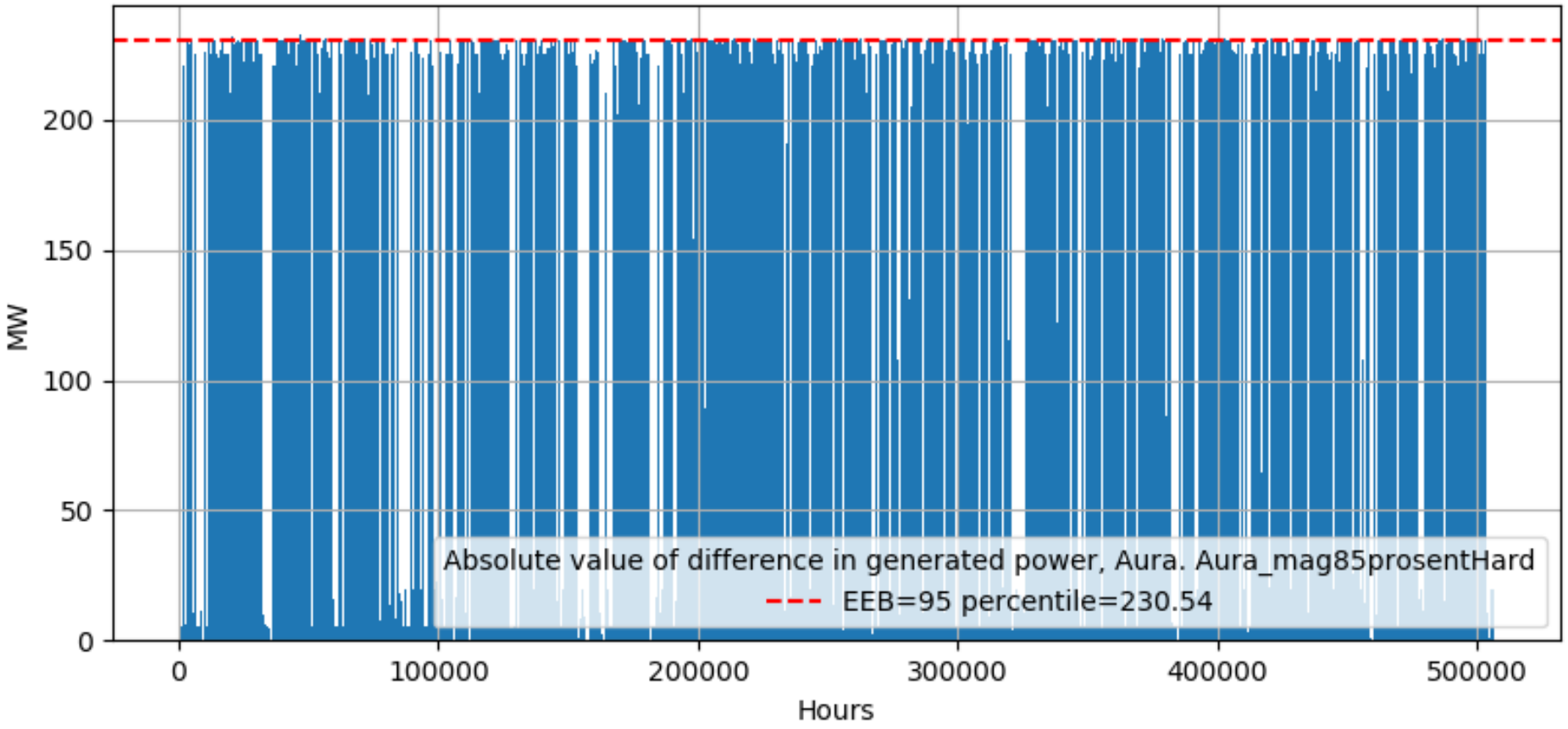
Storage capacity

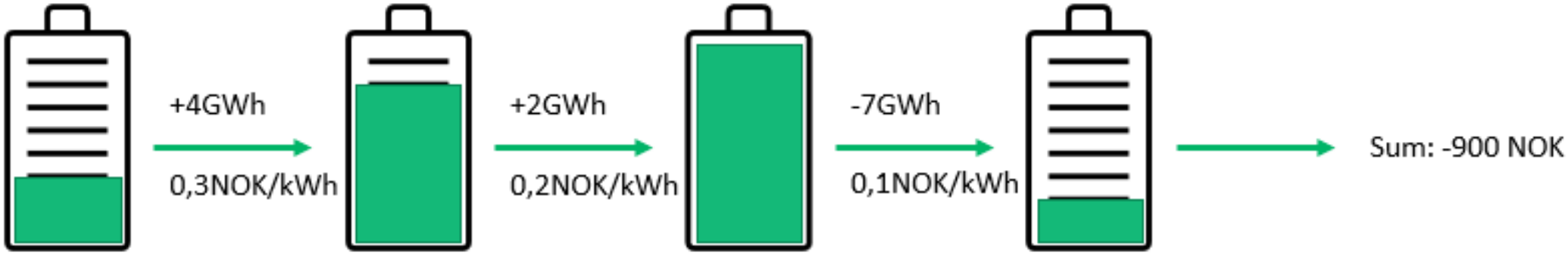


Storage capacity

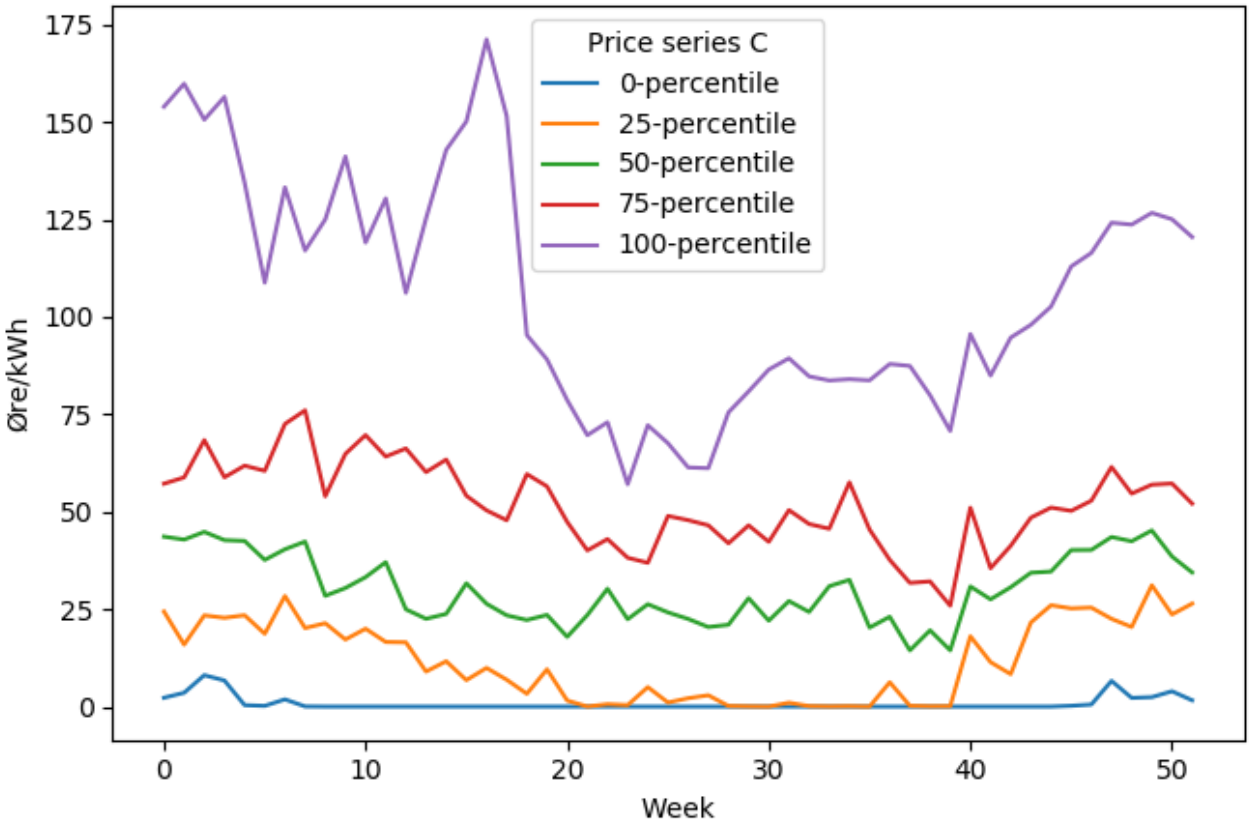


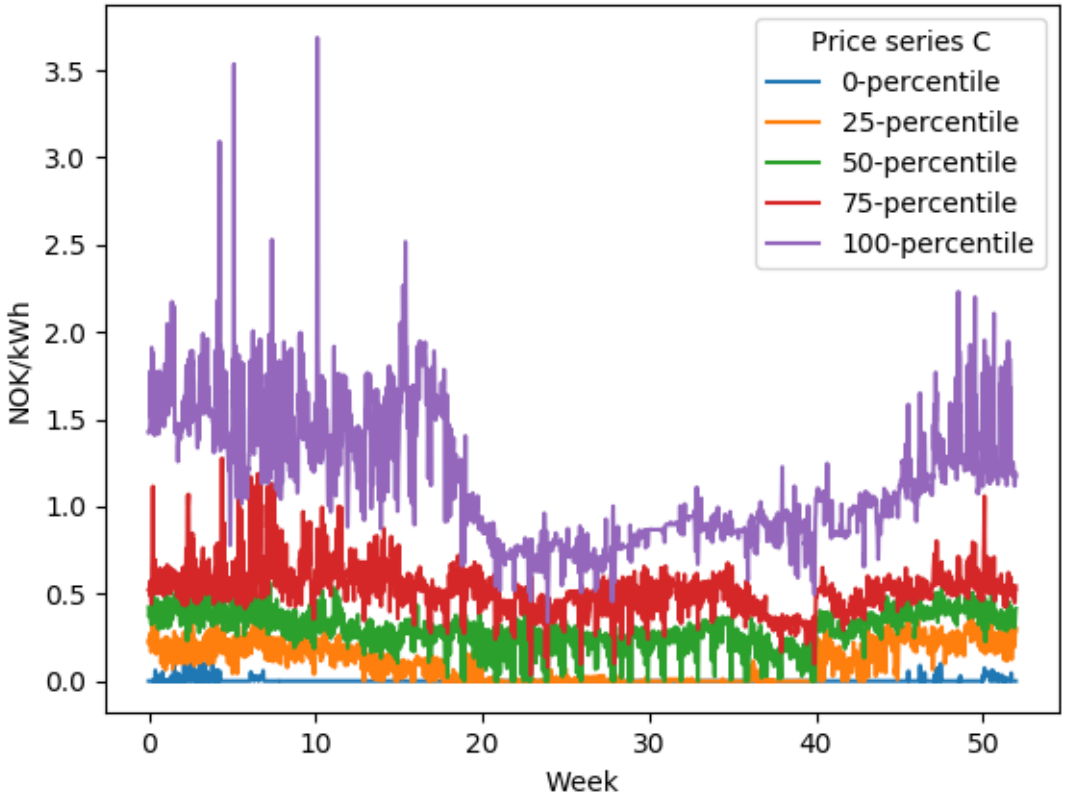

200
150
100
50
0
MW
0
100000
200000
300000
400000
500000
Hours
Absolute value of difference in generated power, Aura. Aura_mag85prosentHard
EEB=95 percentile=230.54

Net income from equivalent storage



Priser


Price series C
0-percentile
25-percentile
50-percentile
75-percentile
100-percentile
Øre/kWh
Week
0
25
50
75
100
125
150
175
0
10
20
30
40
50


Price series C
0-percentile
25-percentile
50-percentile
75-percentile
100-percentile
NOK/kWh
Week
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
0
10
20
30
40
50

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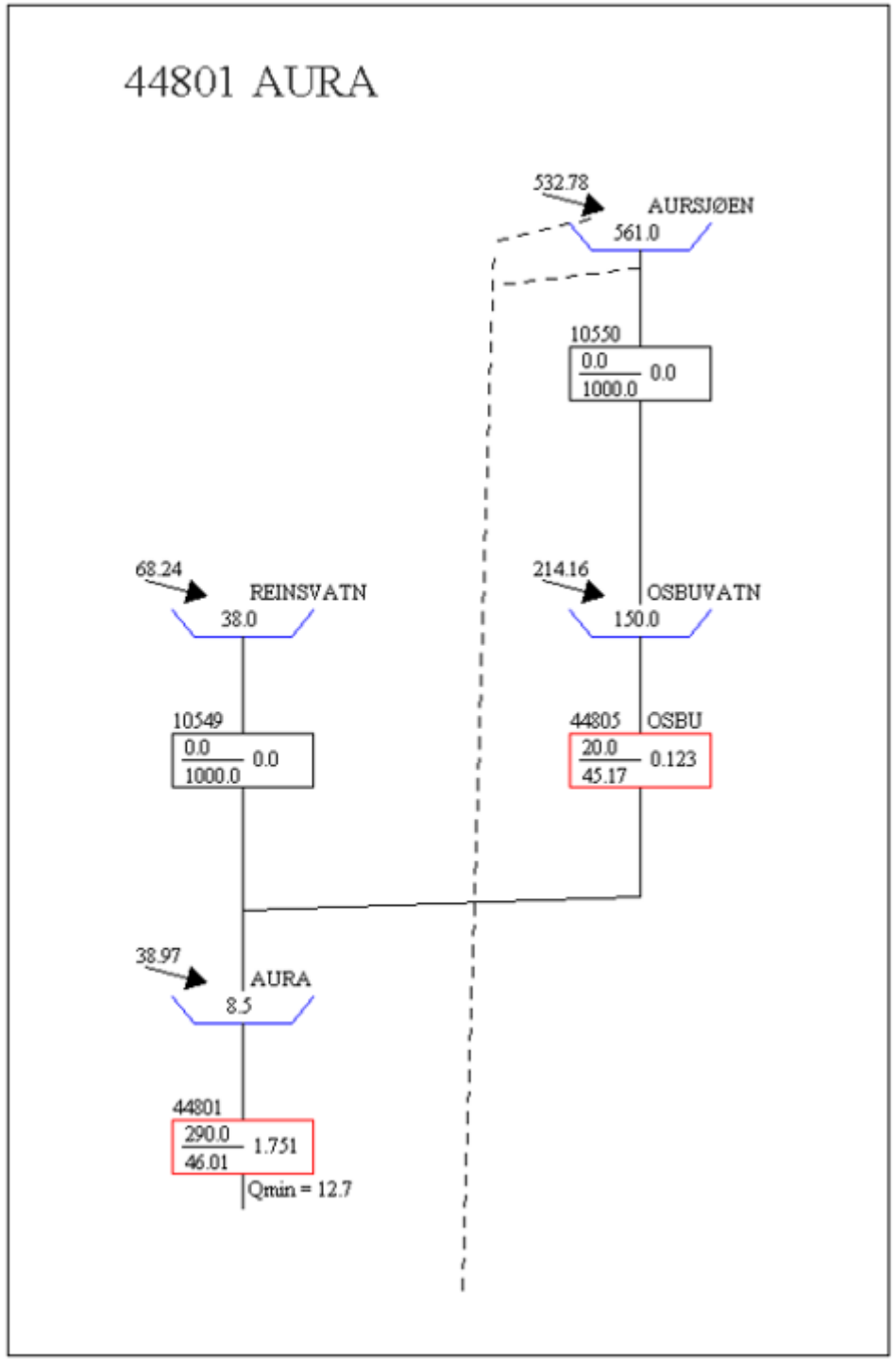

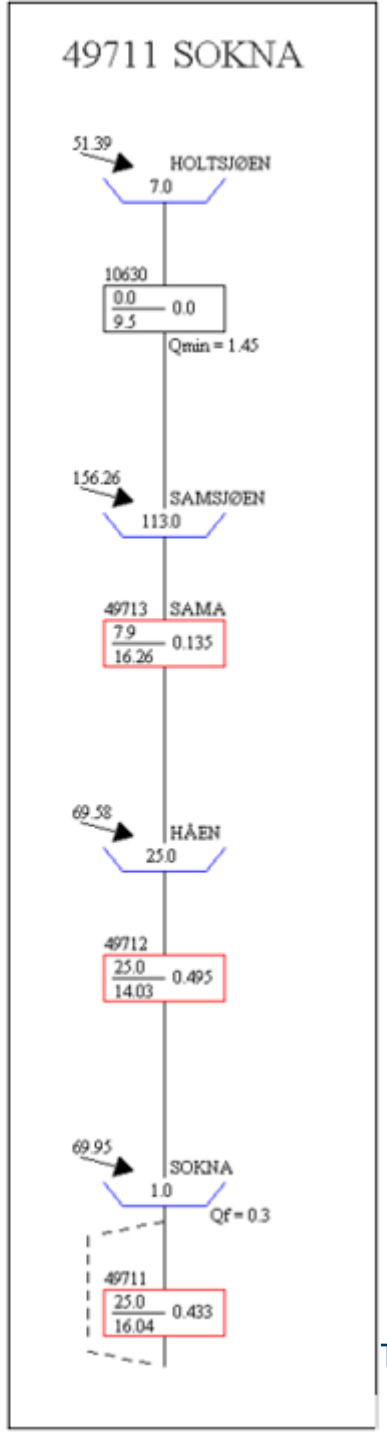

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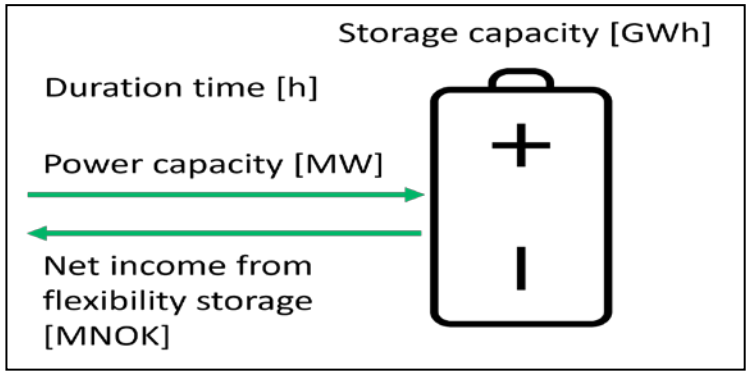
Results



SOKNA	85% limit Stop discharge	85% limit Minimum reservoir
Storage capacity [GWh]	71.38	122.95
Power capacity [MW]	21.10	33.97
Net Income [MNOK]	16.39	188.90
Duration time [h]	2771.0	2874.7
AURA		
Storage capacity [GWh]	469.73	967.15
Power capacity [MW]	198.90	159.61
Net Income [MNOK]	648.57	2710.14
Duration time [h]	2042.7	4205.9

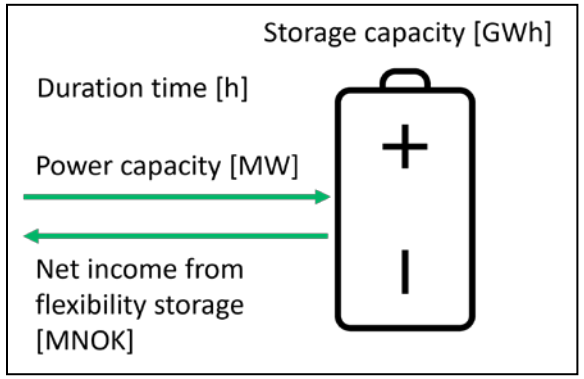
Flexibility factor

SOKNA	Average price [NOK/kWh]	Produced Hydropower [GWh]	Net Income [Mkr]	income/ production	Flexfactor
no restriction	0.35900	318.9	136.15	0.42692	1.18920
85% limit stop discharge	0.35900	318.3	135.45	0.42555	1.18539
85% limit minimum reservoir	0.35900	310.7	126.98	0.40870	1.13845

AURA	Average price [NOK/kWh]	Produced Hydropower [GWh]	Net Income [Mkr]	income/ production	Flexfactor
no restriction	0.35900	1661.00	702.19	0.42275	1.17759
85% limit stop discharge	0.35900	1581.40	671.33	0.42452	1.18250
85% limit minimum reservoir	0.35900	1486.10	568.37	0.38246	1.06534

$$F = \frac{\pi^*}{\bar{\pi}}$$

Take-aways

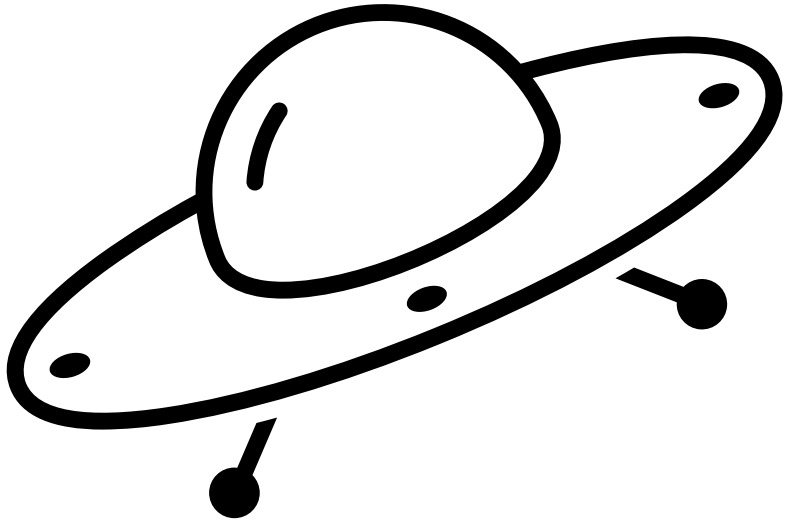


- 3 parameters – describes the flexibility
- Change in the flexibility

$$F = \frac{\pi^*}{\overline{\pi}}$$

- Size of the flexibility
- Snapshot
- Easy to compare, but maybe not understand

Future work



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