HydroCen

NORWEGIAN RESEARCH CENTRE FOR HYDROPOWER TECHNOLOGY

Investing in hydropower system flexibility

Application of decision support tools to a real case in Norway

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Agenda

- Motivation
- Decision support tools
- Investment case(s)
- Assumptions about the future
  - Market prices
  - Inflows
- Model based results
  - Production revenue
  - Reduced economical consequences of planned or forced outages.

Motivation

- Increased amount of new renewables in the European system
- Value of flexibility and storage will increase
  - Norwegian hydro is one such provider of flexibility
- Marked based system
- Individual producer decide on investment and upgrading based on their own assumptions about the future
- Presentation about how some of SINTEFs models are used in the investment decision process
  - Real case from Lyse Kraft and the Røldal Suldal-kraftverkene (RSK) system

Decision support tools

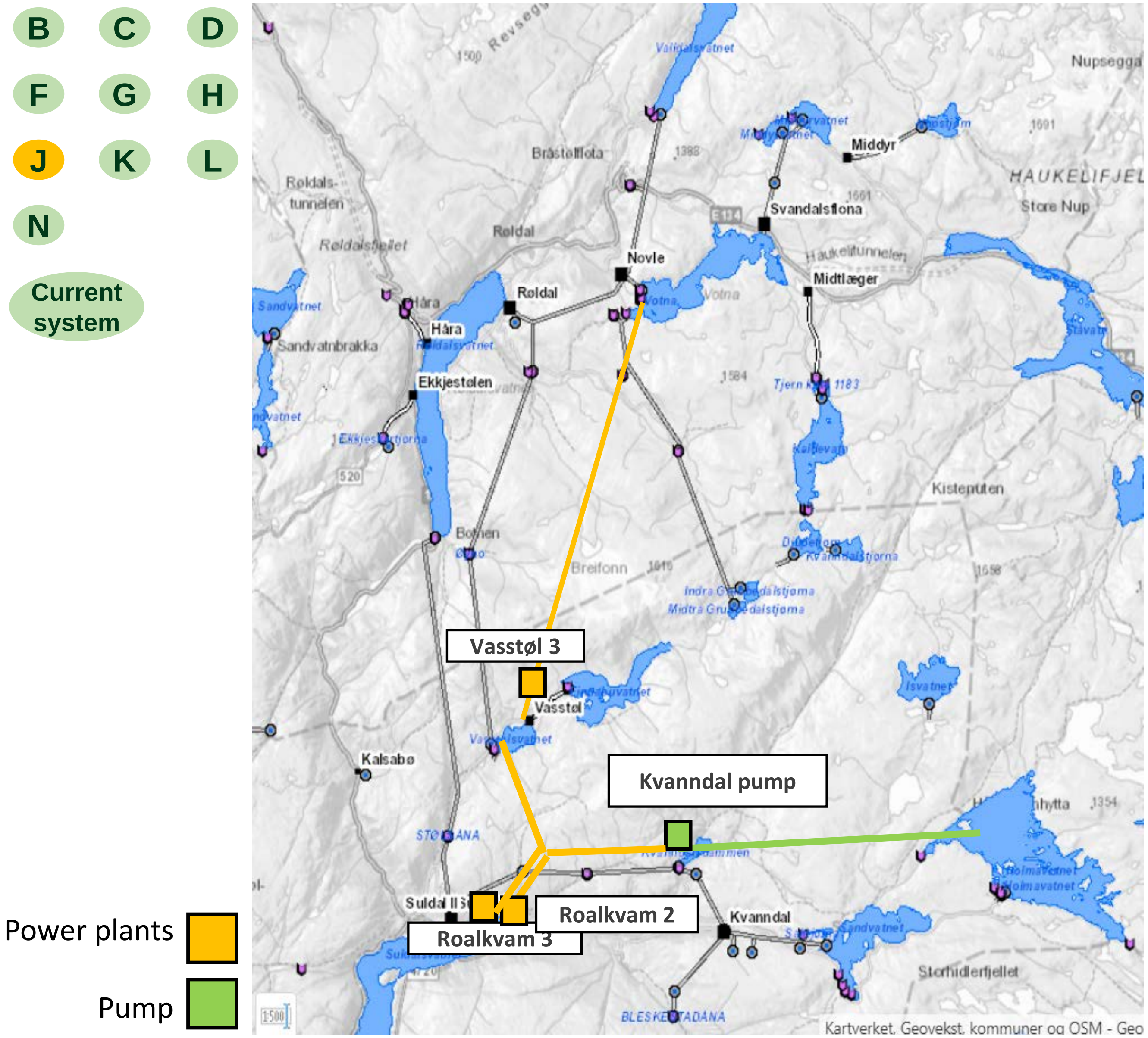
- Price forecasting
  - Fundamental market model: EMPS or FanSi

- Revenue calculations
  - SDDP based model : ProdRisk
  - A new detailed simulator (ProdRisk-SHOP)

Investment cases

A B C D
E F G H
I J K L
M N

Current system



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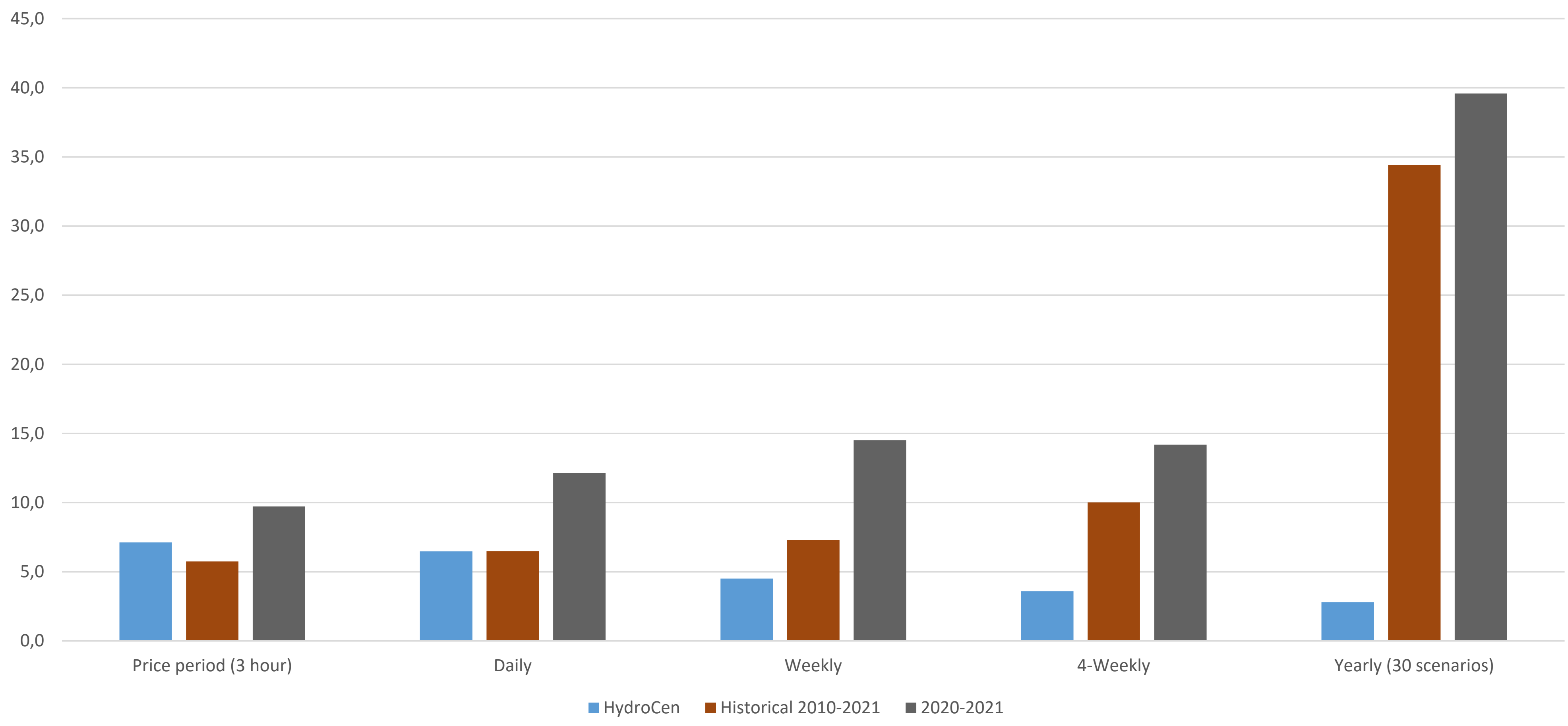
Future market prices

- Basic price scenario from fundamental market model
  - Detailed model of North European system
  - Stage 2030
  - Typical time resolution 3 hours

- Results:
  - Prices referred to 2030 for each time period for different weather years
  - Weather years used to correlate prices with local inflow
- Value of flexibility given by uncertainty and variation
  - Prices from model vs observed uncertainty ?

Price properties - volatility



Scaling of price volatility

A price series $P(t)$ (with 3h-resolution) with average price $\bar{P}$ og period averages $\langle P \rangle_{period}$ the variations δP on each time scale are given by:

- $\delta P_y(t) = \langle P \rangle_{year}(t) - \bar{P}$
- $\delta P_{4w}(t) = \langle P \rangle_{4weeks}(t) - \langle P \rangle_{year}(t)$
- $\delta P_w(t) = \langle P \rangle_{week}(t) - \langle P \rangle_{4weeks}(t)$
- $\delta P_d(t) = \langle P \rangle_{day}(t) - \langle P \rangle_{week}(t)$
- $\delta P_{3h}(t) = P(t) - \langle P \rangle_{day}(t)$
- $\Rightarrow P(t) = \bar{P} + \delta P_y(t) + \delta P_{4w}(t) + \delta P_w(t) + \delta P_d(t) + \delta P_{3h}(t)$

The price variations may then be scaled on each time scale with different factors f:

- $P_{skalert}(t) = \bar{P} + f_y \delta P_y(t) + f_{4w} \delta P_{4w}(t) + f_w \delta P_w(t) + f_d \delta P_d(t) + f_{3h} \delta P_{3h}(t)$

Future inflows

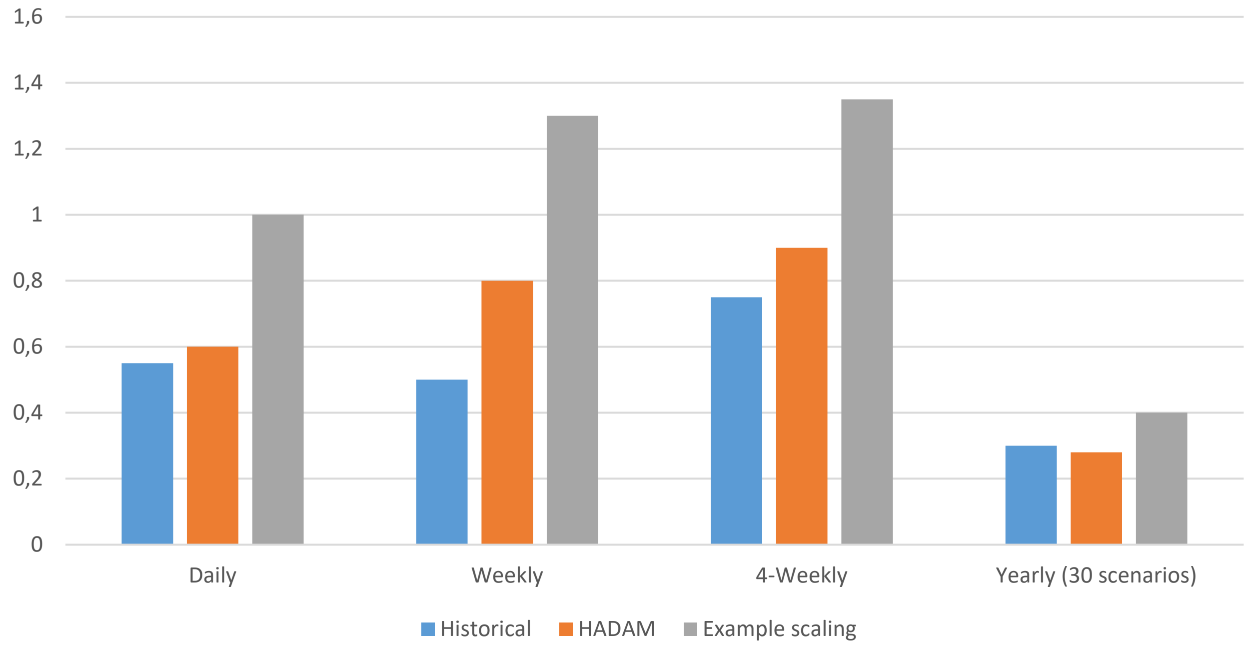
- Based on historical observations

- Adjustment to include climate change
  - Basic correction factors from a Nordic Climate project
  Climate and Energy Systems - CES | Icelandic Meteorological office (vedur.is)

  - Yearly average volume
  - Yearly profile
  - Volatility (variation at different time scales: day, week, month and year)

  - Several "possibilities" for climate change

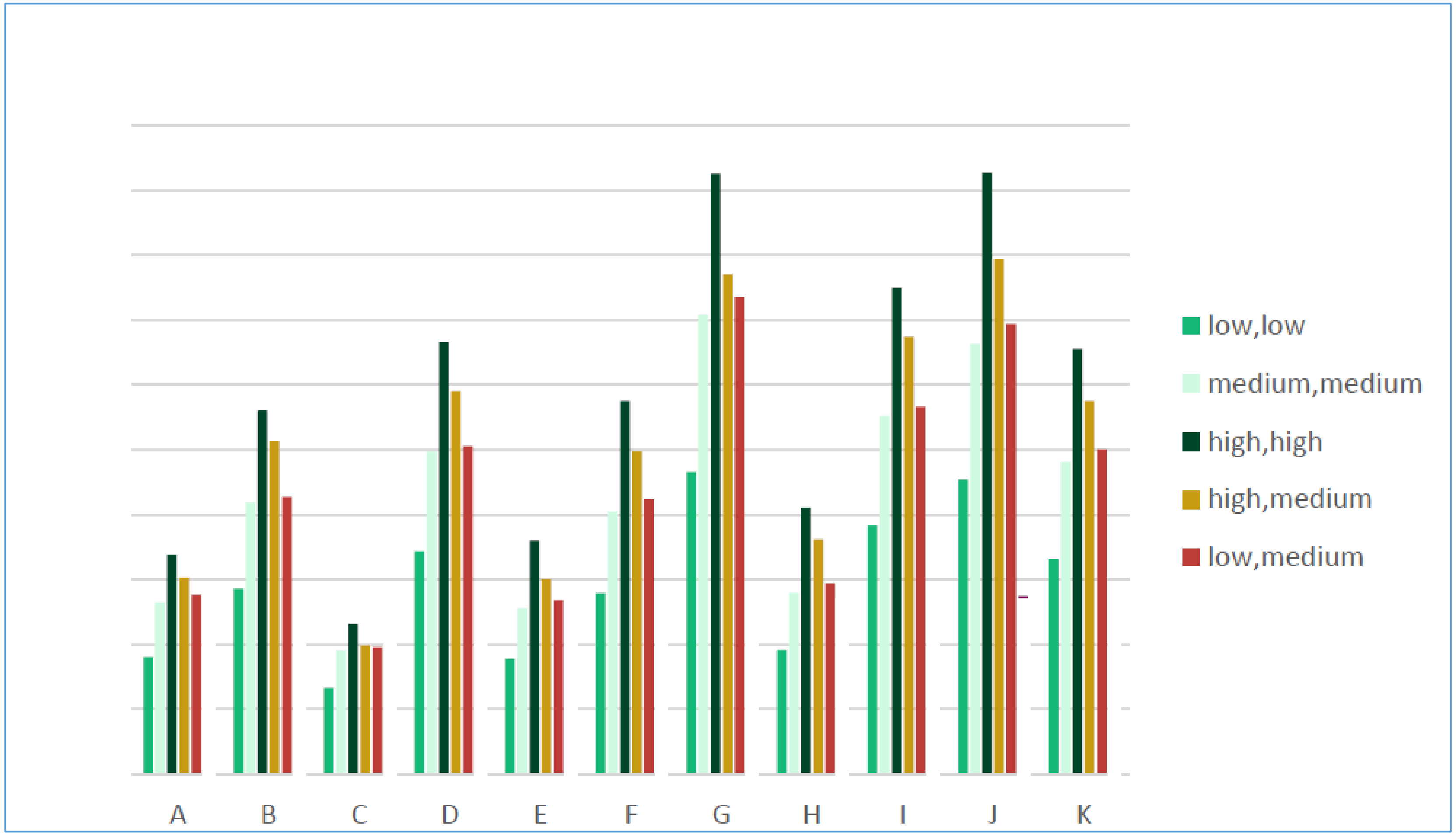
Inflow properties - volatility



Model based simulation results

- Production revenue
  - 90 optimizations
- Reduced economical consequences of planned or forced outages.
  - 482 optimizations / simulations

Increase in production revenue



Economical consequences of forced outages

Current system

	2	4	8	12
4	-1.3	-3.9	-9.0	-14.1
13	-1.3	-3.2	-6.7	-10.0
22	-1.0	-2.9	-5.6	-8.5
30	-1.0	-2.0	-4.1	-6.1
39	-0.4	-1.1	-4.2	-8.9
48	-1.3	-3.0	-7.5	-13.6

Investment case J

	2	4	8	12
4	-0.5	-1.7	-4.4	-8.2
13	-0.5	-1.3	-3.4	-5.6
22	-0.2	-1.0	-2.7	-4.2
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39	-0.2	-0.3	-1.5	-3.5
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A new detailed simulator (ProdRisk-SHOP)