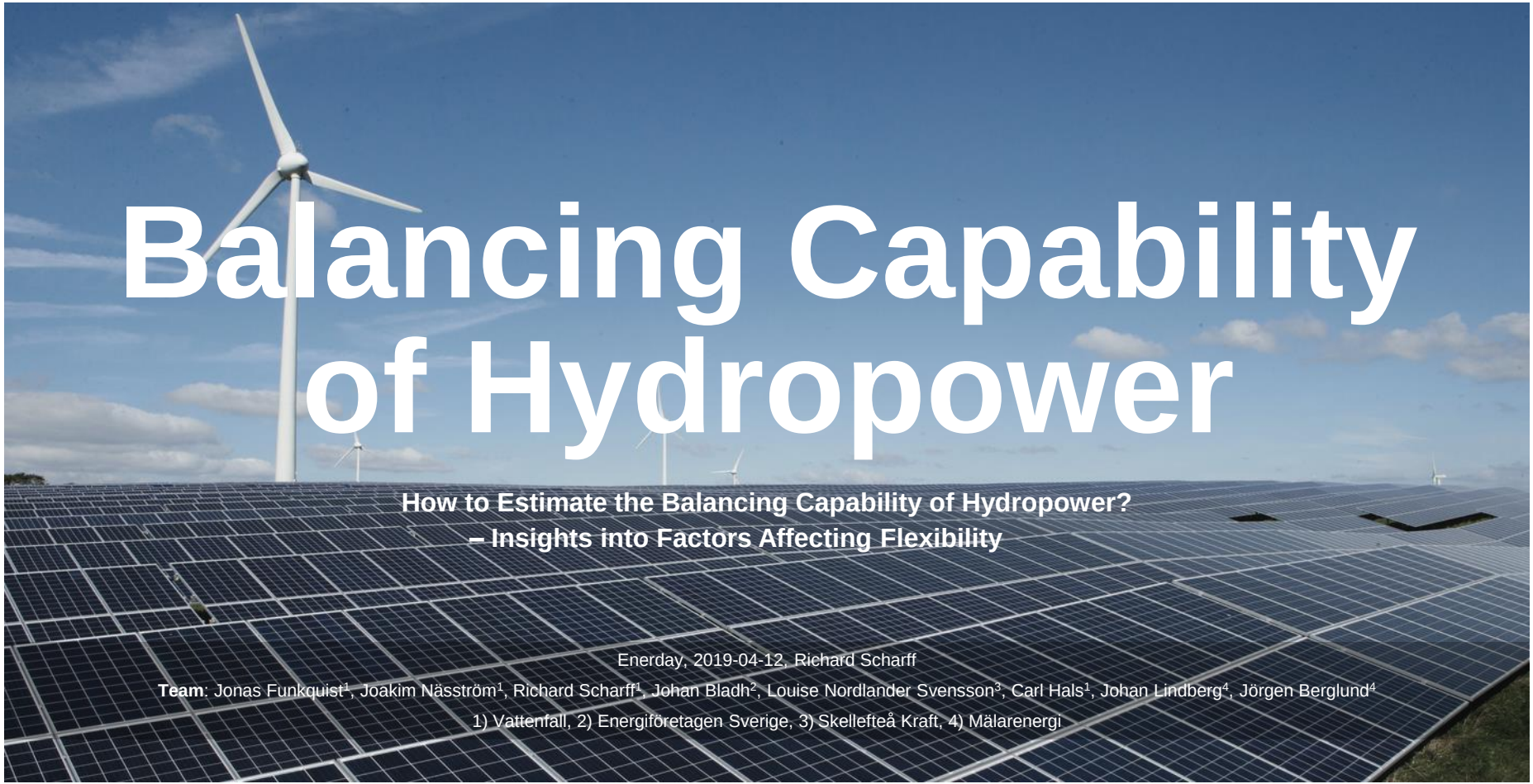


Balancing Capability of Hydropower

How to Estimate the Balancing Capability of Hydropower? – Insights into Factors Affecting Flexibility

Enerday, 2019-04-12, Richard Scharff

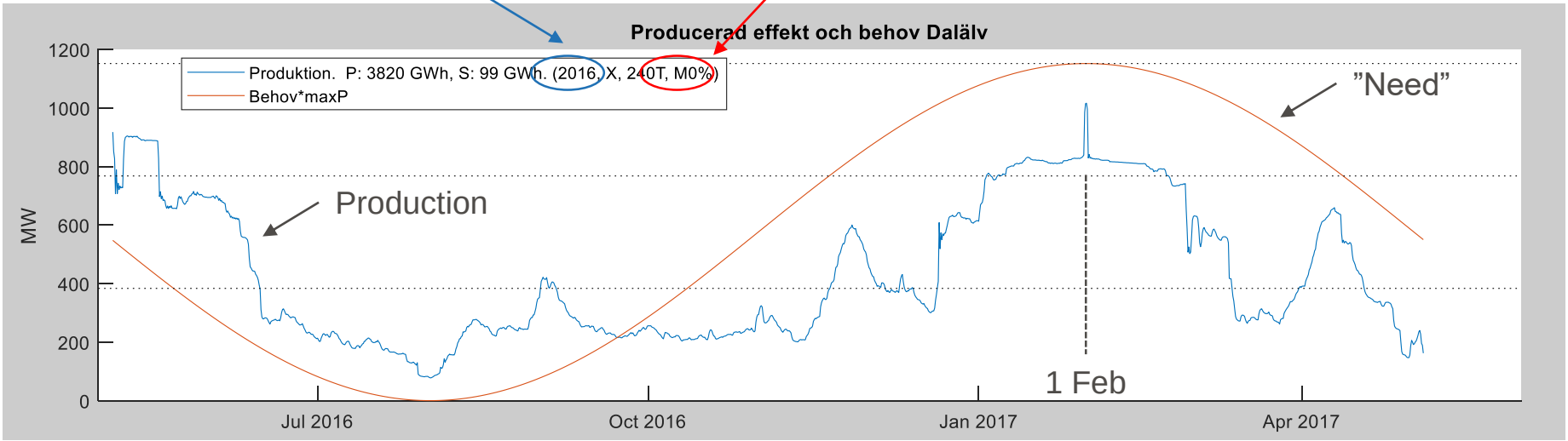
Team: Jonas Funkquist[1], Joakim Näsström[1], Richard Scharff[1], Johan Bladh[2], Louise Nordlander Svensson[3], Carl Hals[1], Johan Lindberg[4], Jörgen Berglund[4]

1) Vattenfall, 2) Energiföretagen Sverige, 3) Skellefteå Kraft, 4) Mälarenergi

How results look like

2016 was a ”dry year” (historical inflows used)

”M0%” = purely seasonal pattern, no multiday variations



- $\max \sum_t P(t)B(t)$, where $P(t)$ is the production and $B(t) = (0,1)$ a ”need” at time t.
- Resolution: 6 hours.

- Hydrological balances for all reservoirs
- $Production = f(discharge)$
- Permits (levels & flows)

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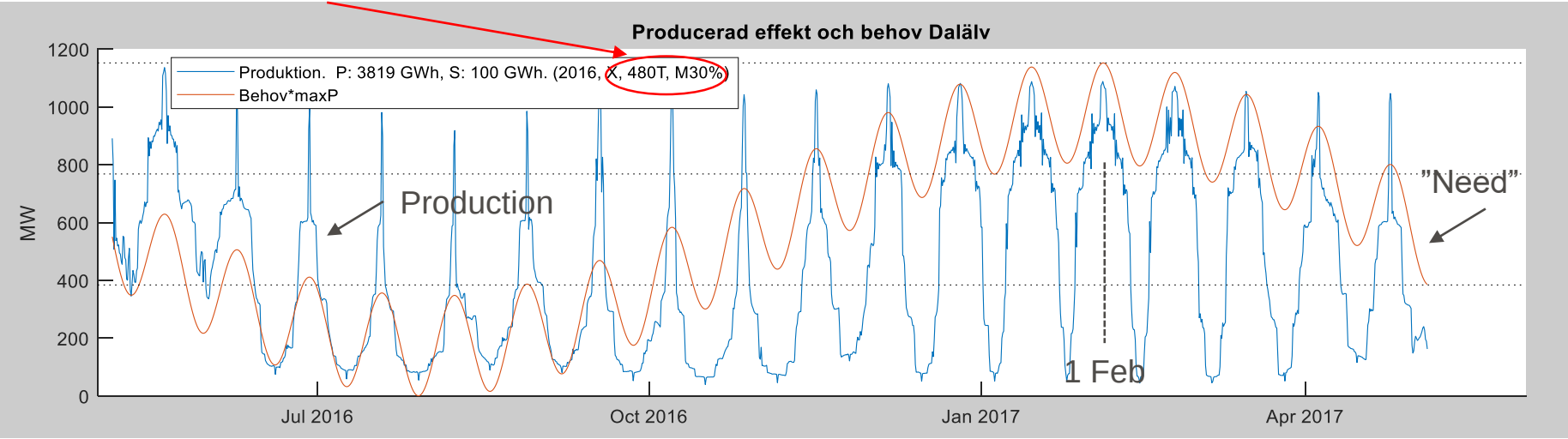
How results look like

”480T, M30%” = same seasonal pattern but with superimposed cosinius (periodtime 480 hours = 20 days)



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Balancing capability

≠ energy yield ⚠

- Being able to **contribute** to balance **any** residual load **pattern**
- Short time horizons: being **fast** (power)
- Long time horizons: being **durable** (power & energy)

- **Focus**: high demand periods

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Balancing vRES

Seitevare

Norway Wants to Be Europe's Battery

A new HVDC line will let Europe store more wind energy in Norway's hydropower system

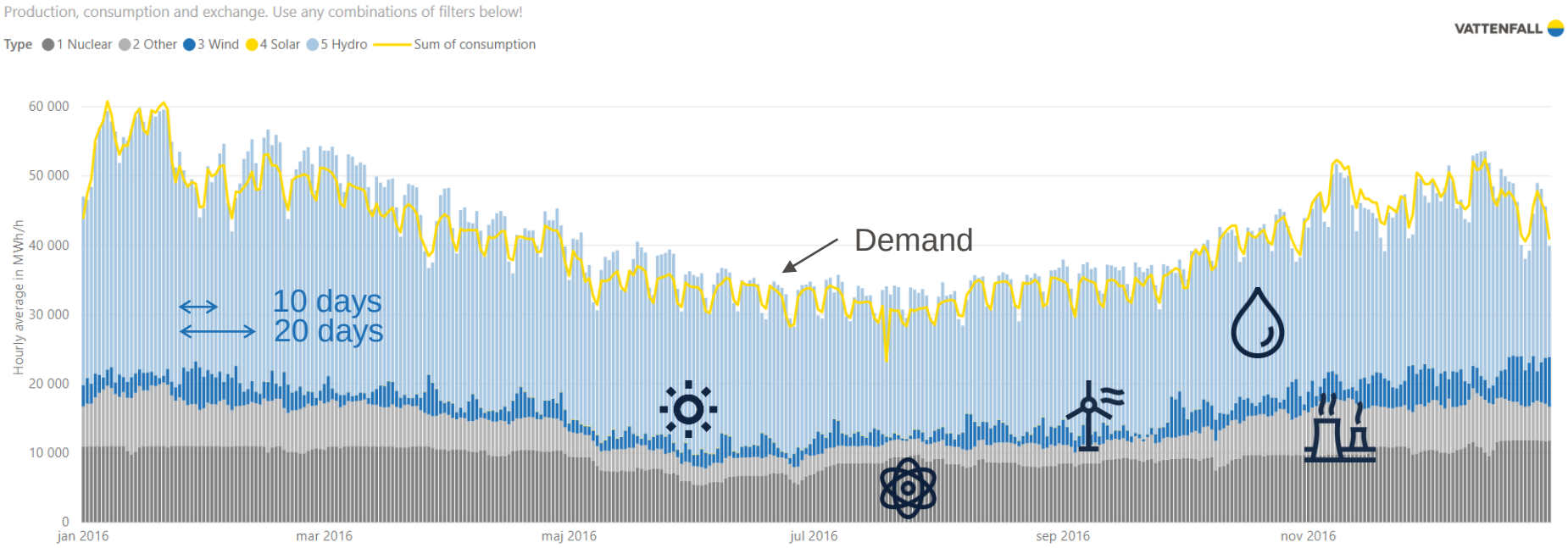
By **Peter Fairley**

Photo: Statnett

The Viking Connection: A new high-voltage DC cable will connect Denmark to Norway.

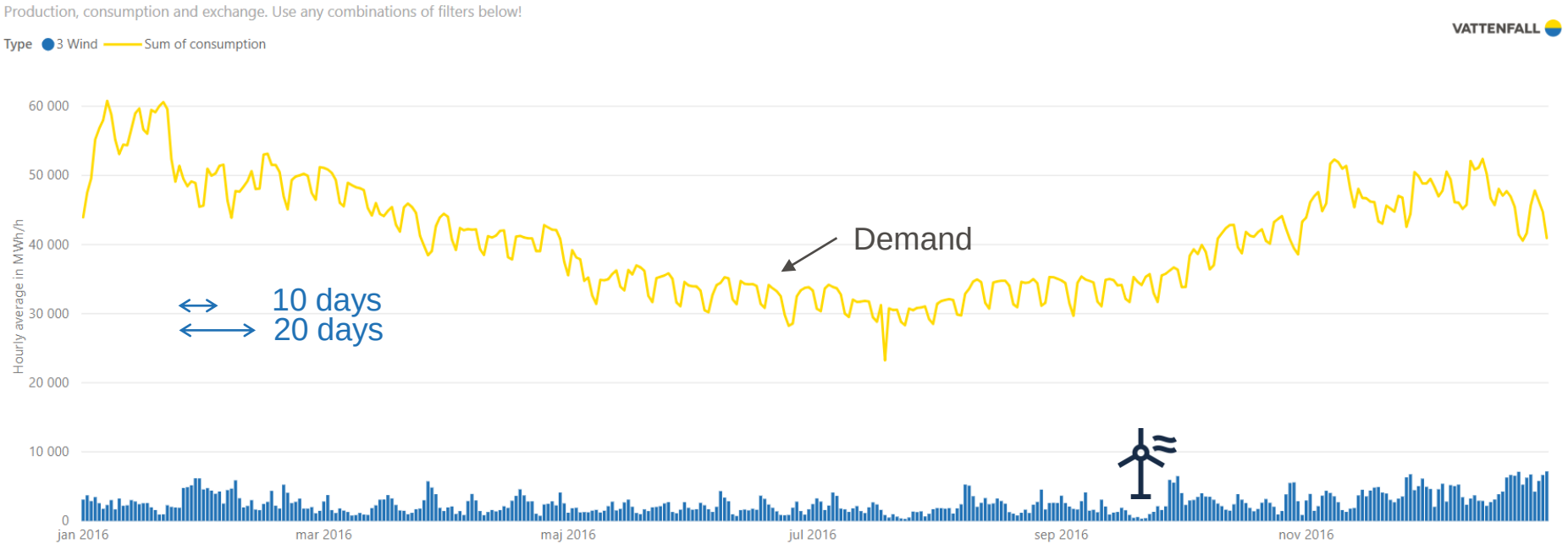
IEEE Spectrum 2014-10-21: https://spectrum.ieee.org/green-tech/wind/norway-wants-to-be-europes-battery

Nordic synchronous area



Online tool accessible on: https://app.powerbi.com/view?r=eyJrIjoiZWQxZjk1ZDAtMjhmZi00YTYxLTlkYzQtNjkzMjhiNDAzNTBlIiwidCI6ImY4YmUxOGE2LWY2NDgtNGE0Ny1iZTczLTg2ZDZjNWM2NjA0ZCIsImMiOjh9

Nordic synchronous area



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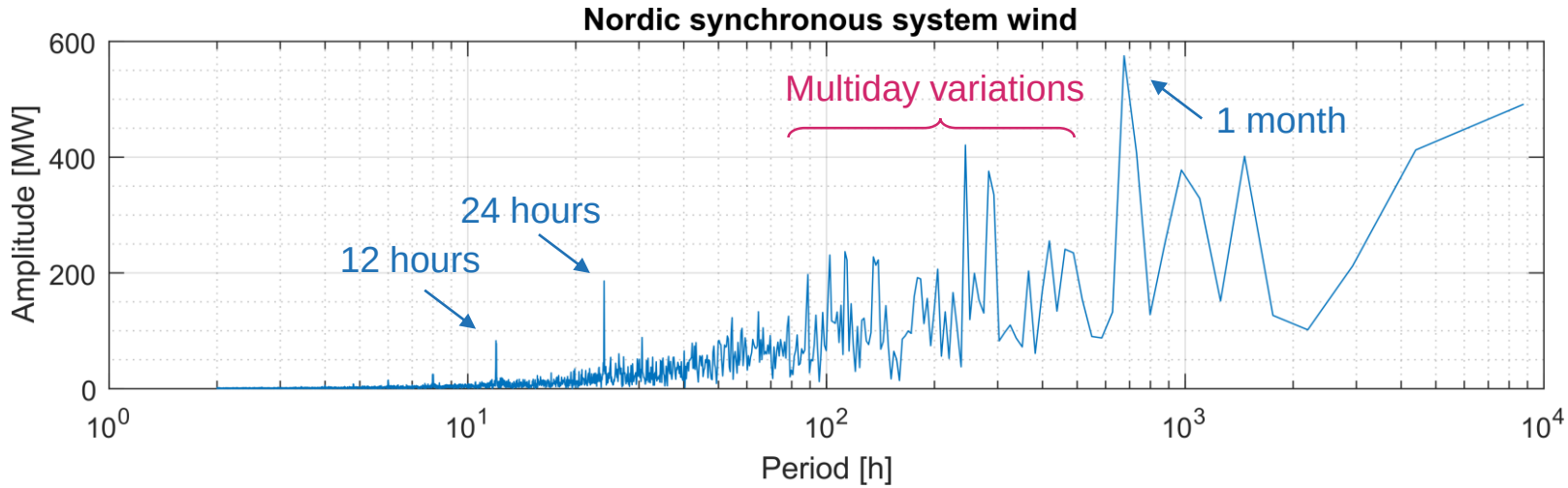
Nordic synchronous area



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Reduce environmental impacts

Letsi

Suorva

Fish migration

E.g. fish ladder

Bypass

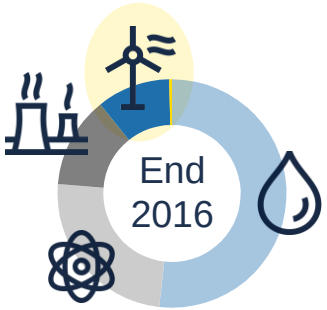
Test facility
Älvkarleby

Upstream & downstream

"Laxelerator"

Wellfare

Installed capacity
Nordic syncronous area:



- Ecological value & power system value

Demand
?

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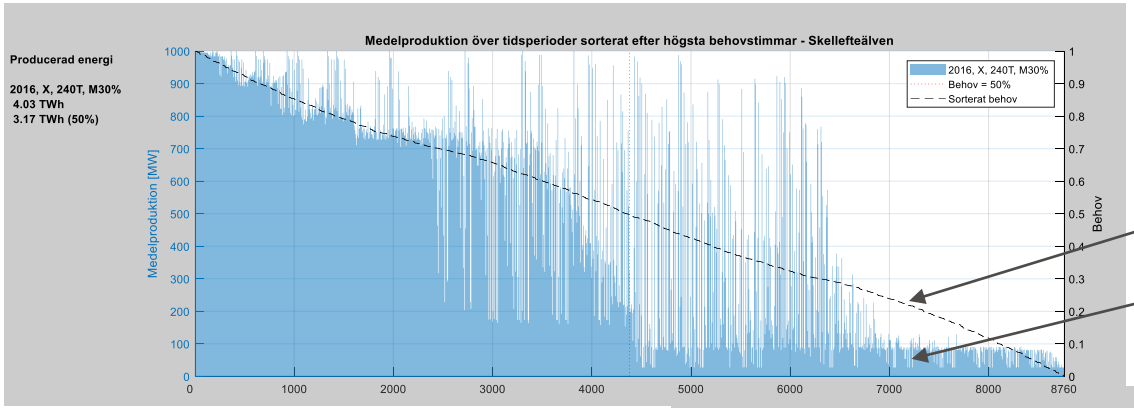
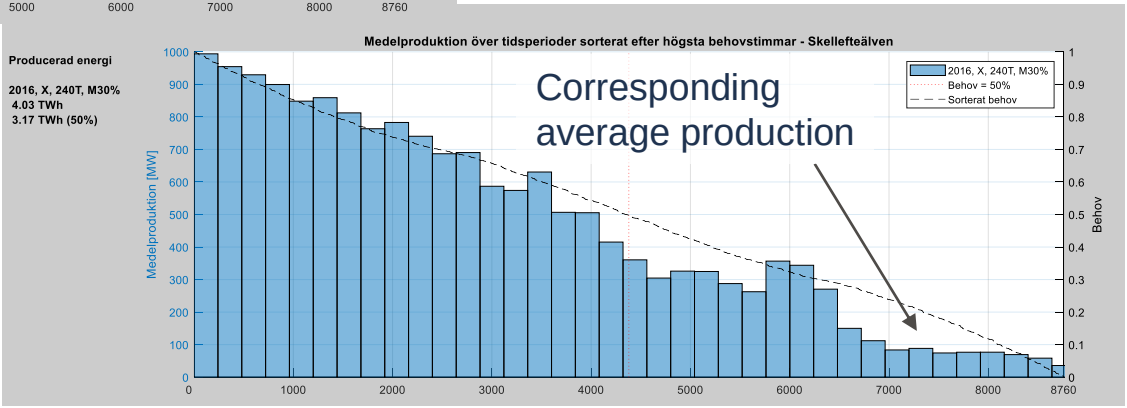
Effects of environmental measures



”Need”: duration curve

Corresponding production

Average production
(240 hours)



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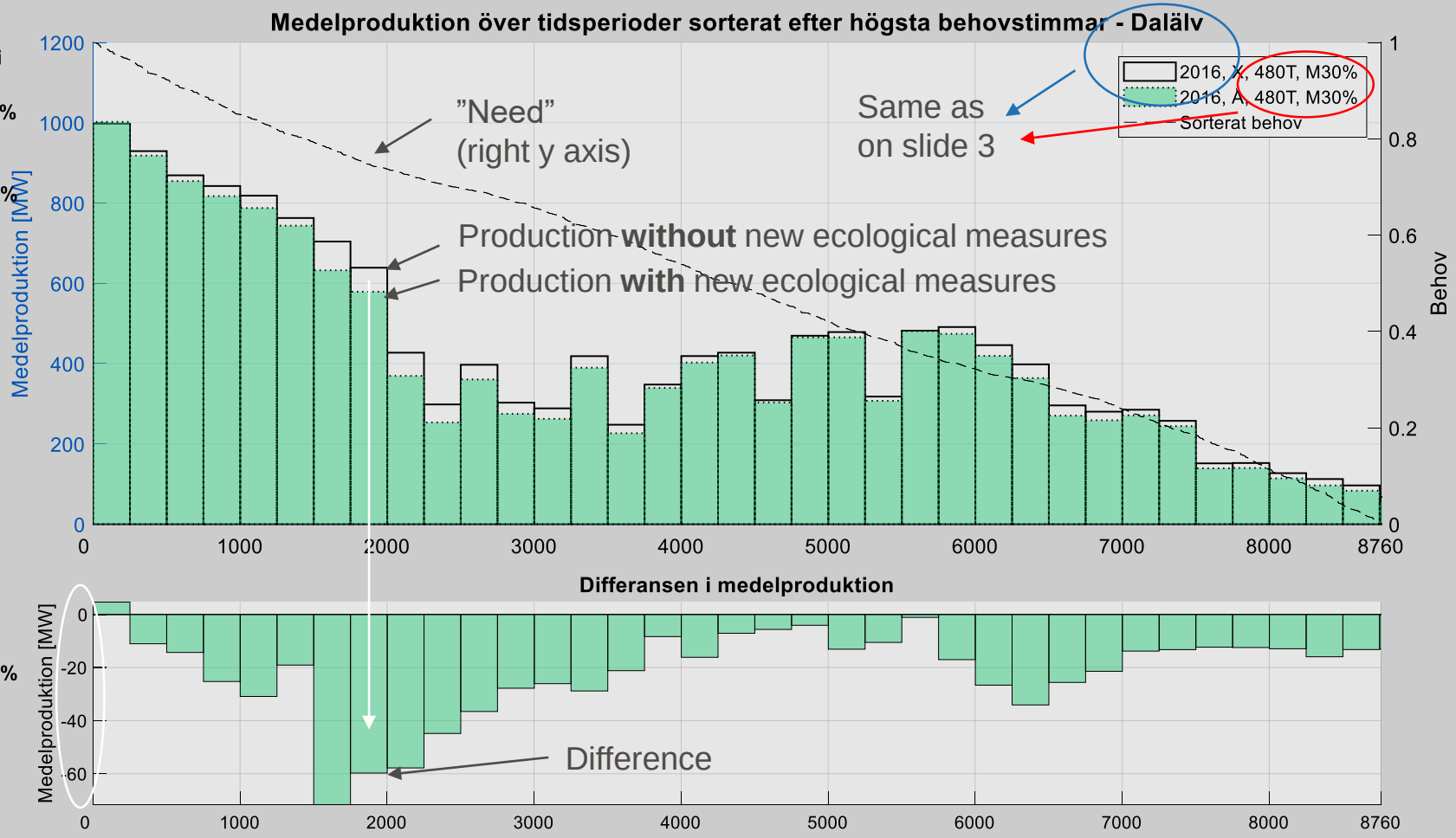
Producerad energi

2016, X, 480T, M30%
3.82 TWh

2016, Å, 480T, M30%
3.63 TWh



Skillnad i energi

2016, Å, 480T, M30%
-189.05 GWh

What affects flexibility?

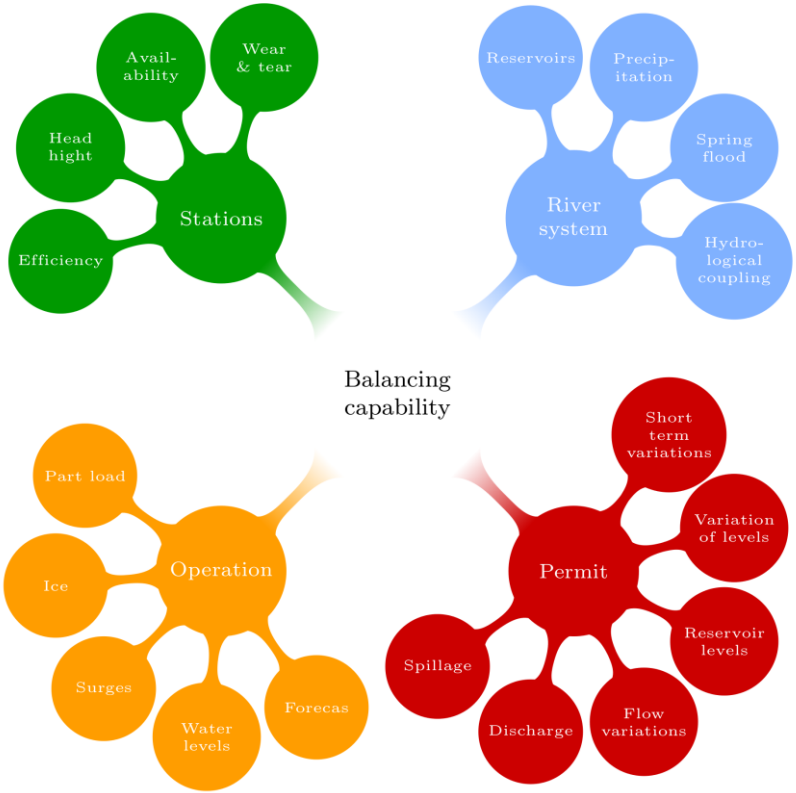
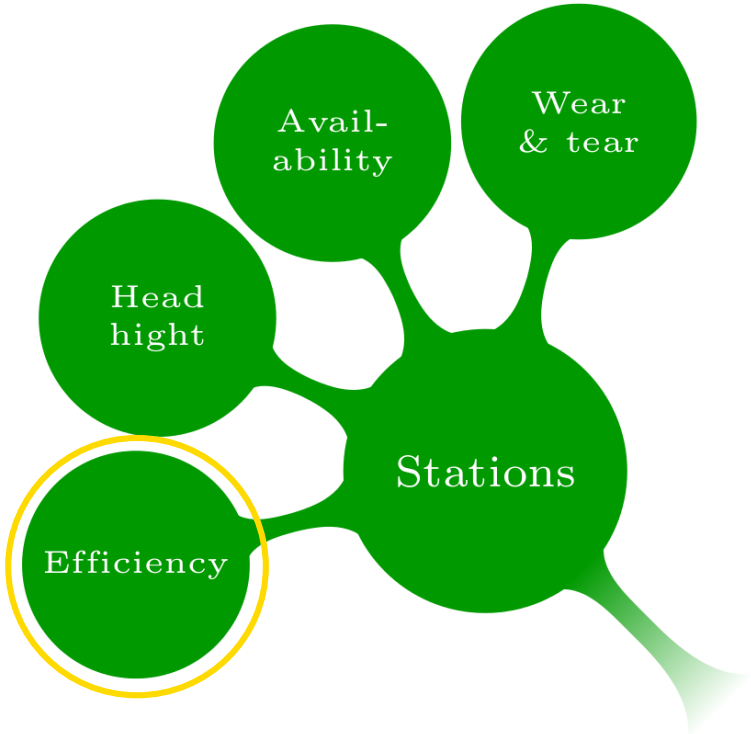
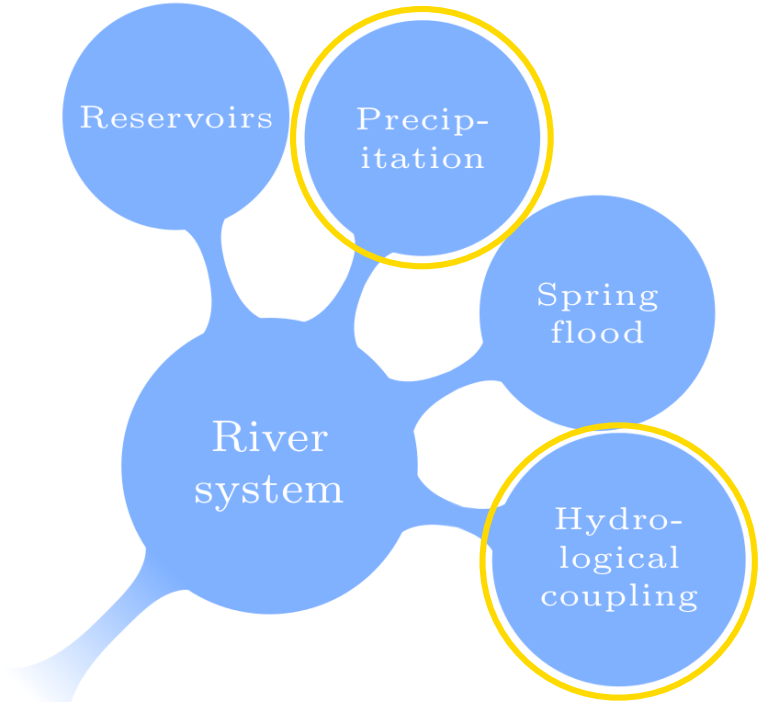


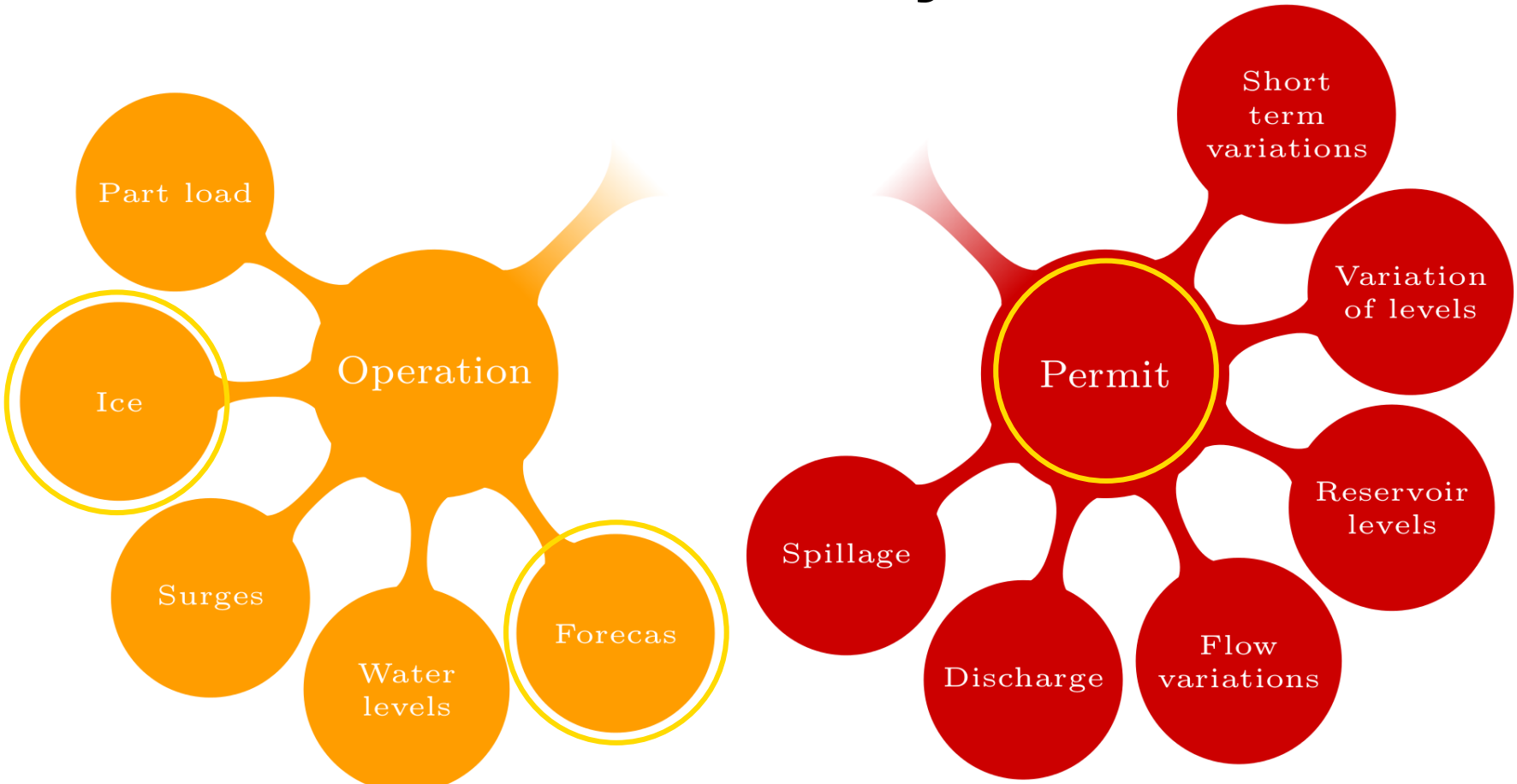
Figure: Factors which affect the balancing capability of hydropower.

What affects flexibility?





What affects flexibility?



Pros & cons

- ✕ **Deterministic** inflows.
- ✕ Deterministic demand.
- ✕ Restrictions regarding **short-term variations** not fully implemented.
- ✕ Assumes **one** optimisation **problem per river** system.
- ✕ Simplifications, e.g. head losses.

- ○ Pattern of ”need” is harmonic which allows for ”recharging”.
- ○ Results and data likely to become publically available [in Swedish].

- ✓ Easy ☺
- ✓ Parametrised ”need”: only **ratio season/multiday** affects results.
- ✓ Well suited to **assess** changes in permits as well as impacts of technical **restrictions**.
- ✓ **Data** included for the ten largest river system in Sweden (largest in terms of energy produced in hydro power stations).

Leitaure delta, picture: Fabian Balk.