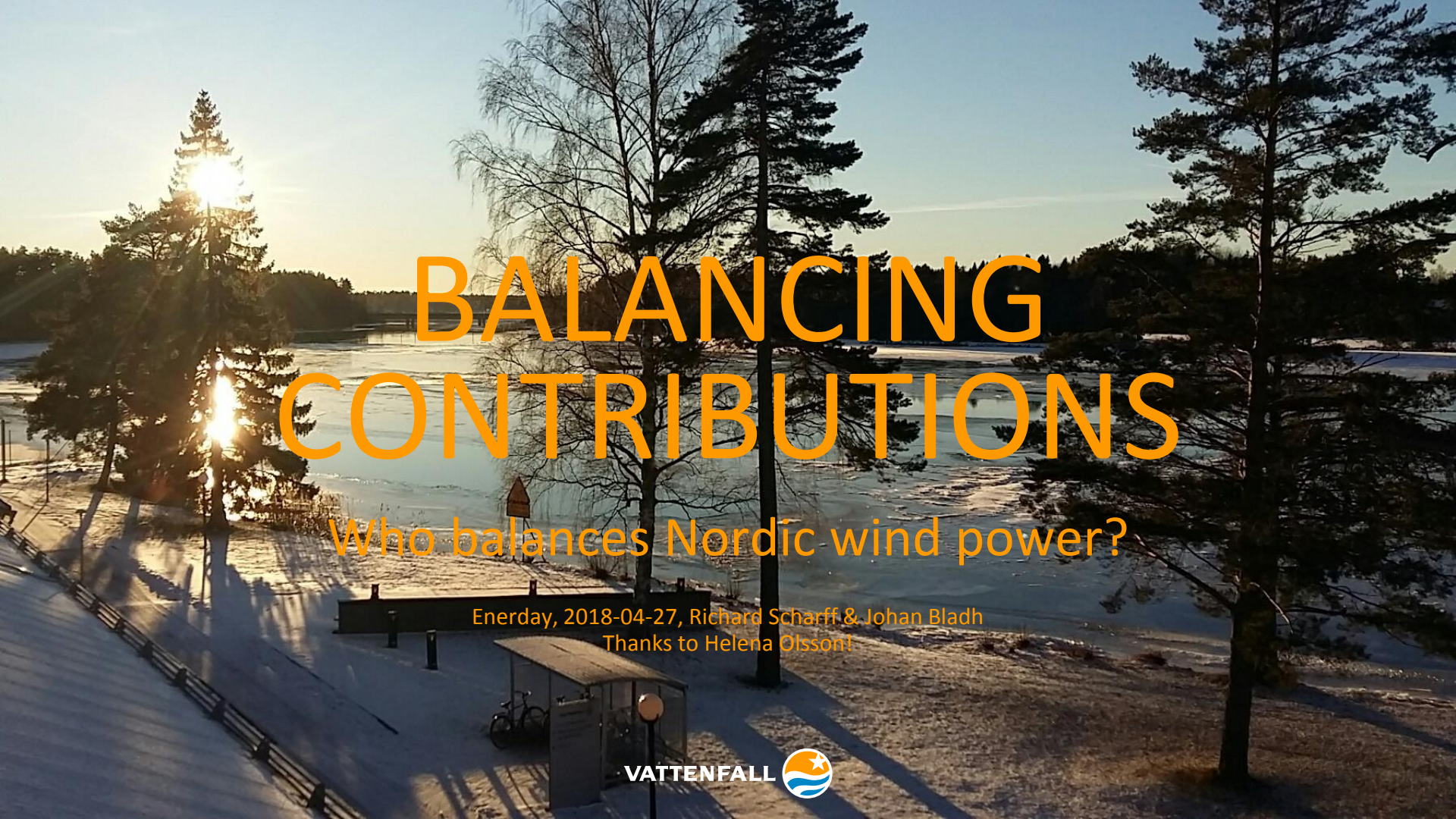


BALANCING CONTRIBUTIONS

Who balances Nordic wind power?

Enerday, 2018-04-27, Richard Scharff & Johan Bladh
Thanks to Helena Olsson!

VATTENFALL

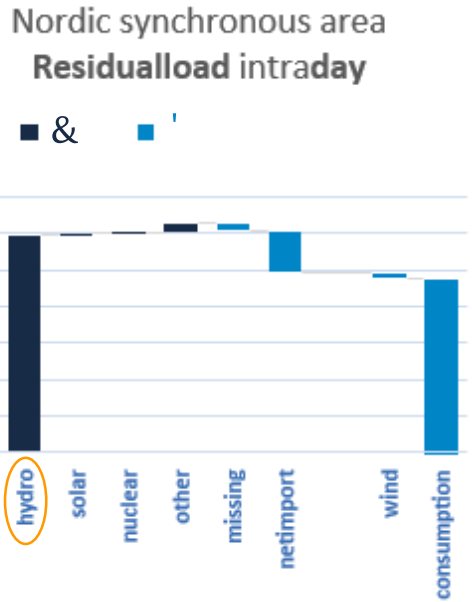
Who balances Nordic wind power?

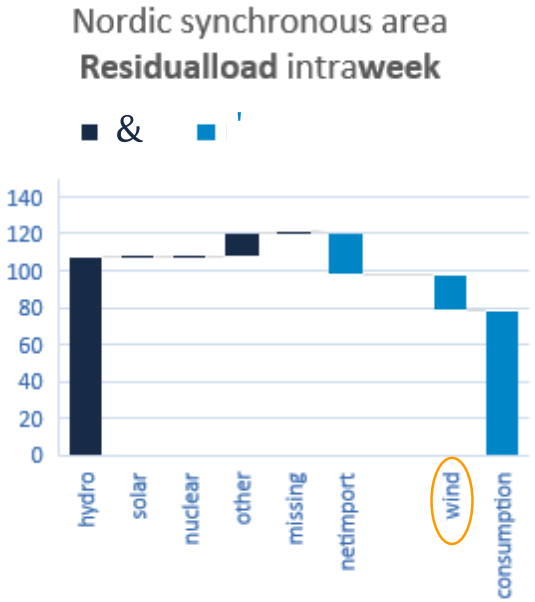
VATTENFALL

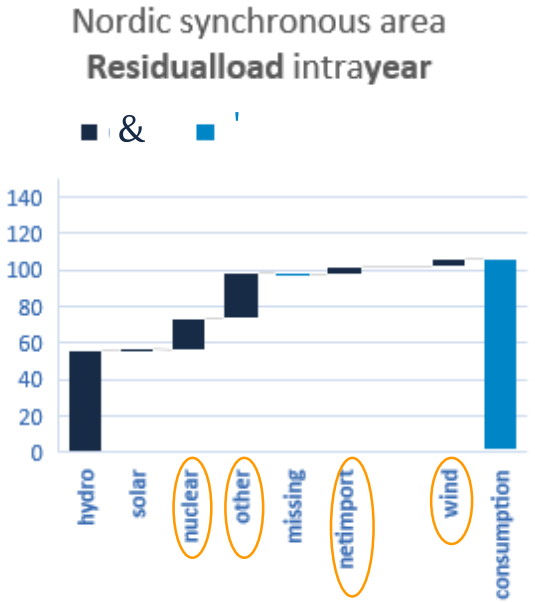
SOME RESULTS

Residualload (t) = consumption (t) – wind (t)

Balancing contribution in %







VATTENFALL

Who balances Nordic wind power?

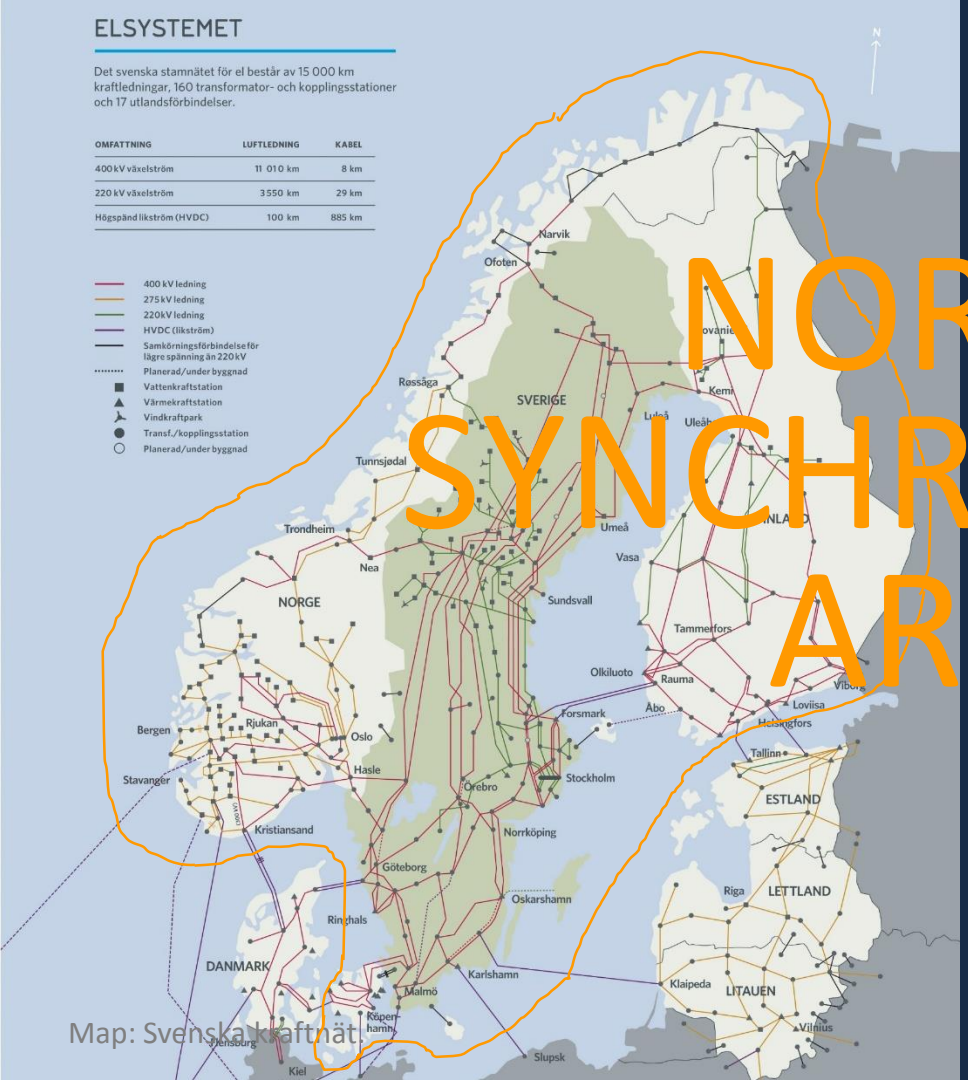
VATTENFALL

Bild: NASA/NOAA.

BALANCING (

Who balances Nordic wind power?

VATTENFALL



NORDIC SYNCHRONOUS AREA

Map: Svenska kraftnät

Who balances Nordic wind power?

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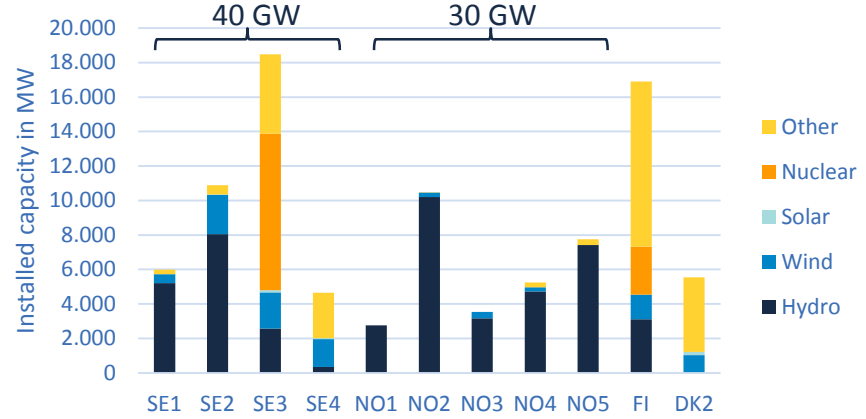
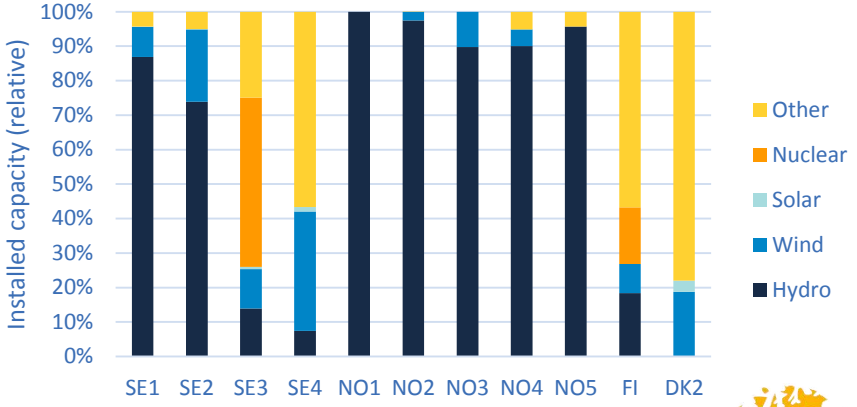
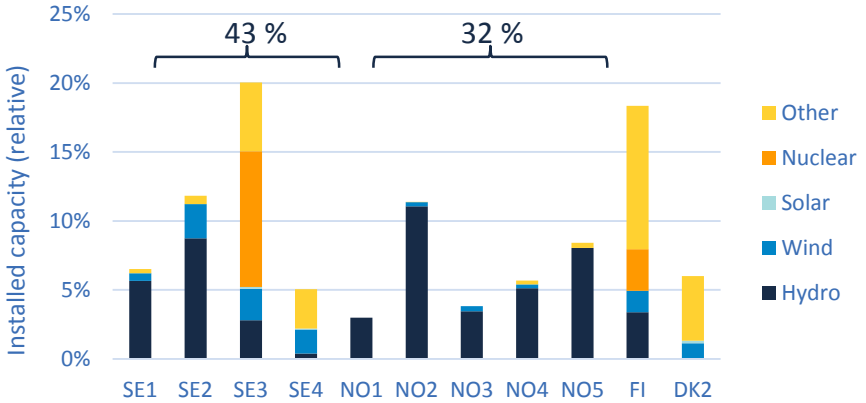
Power plants by 1 January 2017



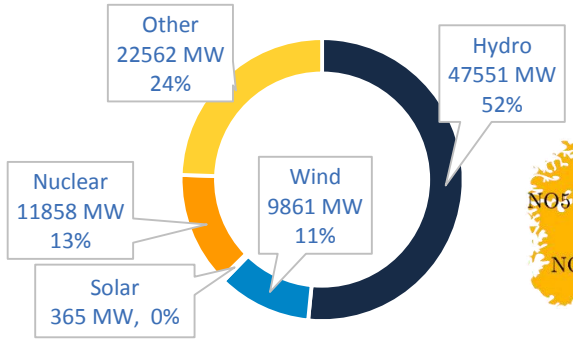
Capacity mix by 1 January 2017

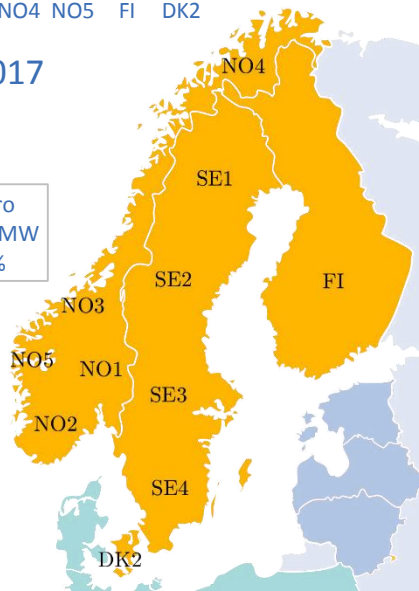


Power plants by 1 January 2017 (relative)



Power plants by 1 January 2017 Nordic syncronous area





Data: Entso-E, SvK, Energiföretagen.

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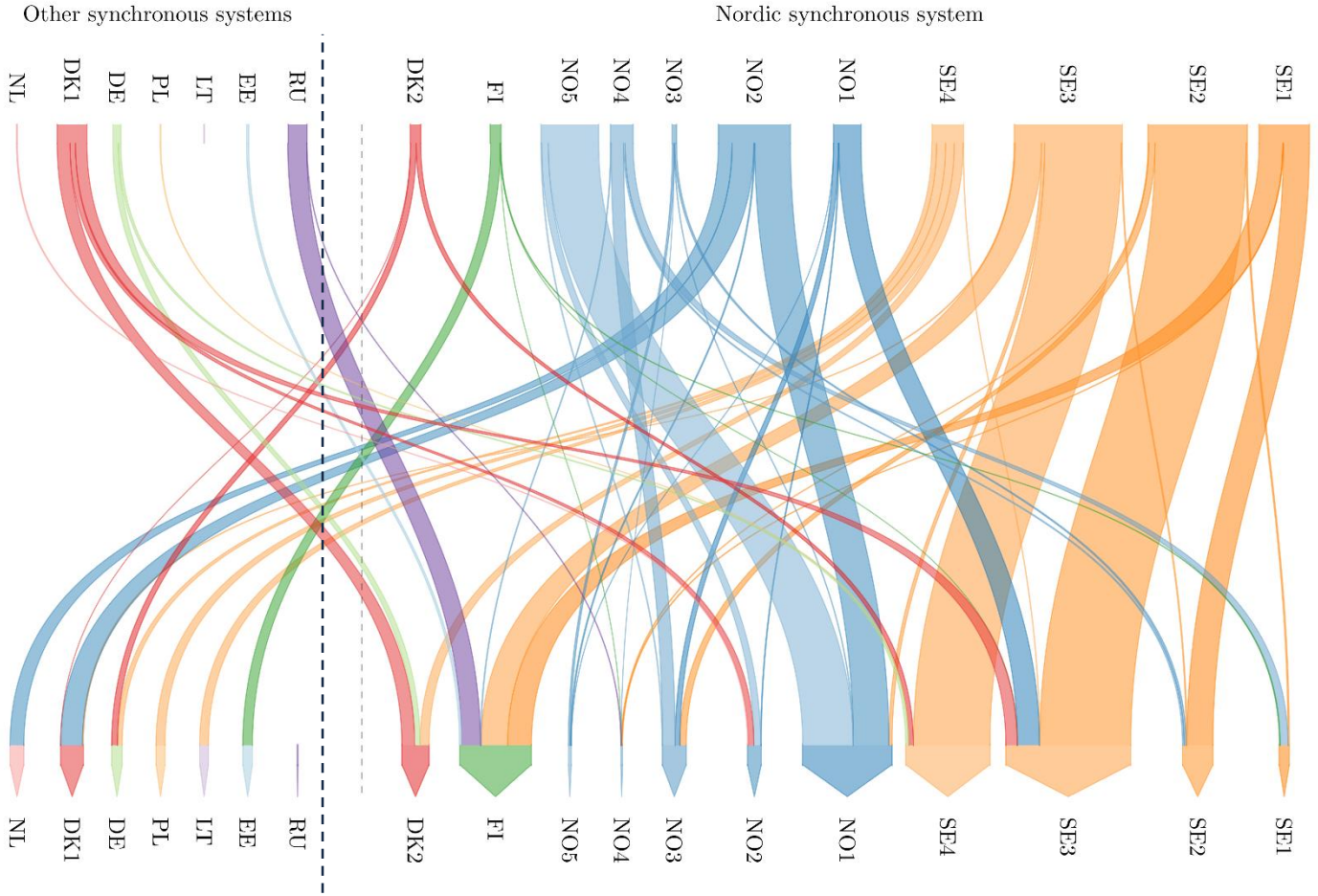
Exchanges during **2016** between the price areas in the Nordic synchronous area and towards other neighbouring systems. Resolution of input data: hourly net exchanges. 2016 was a year with low inflow in hydro reservoirs (”**dry** year”).



Data: Nord Pool.

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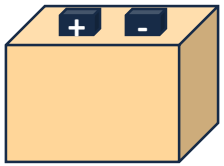
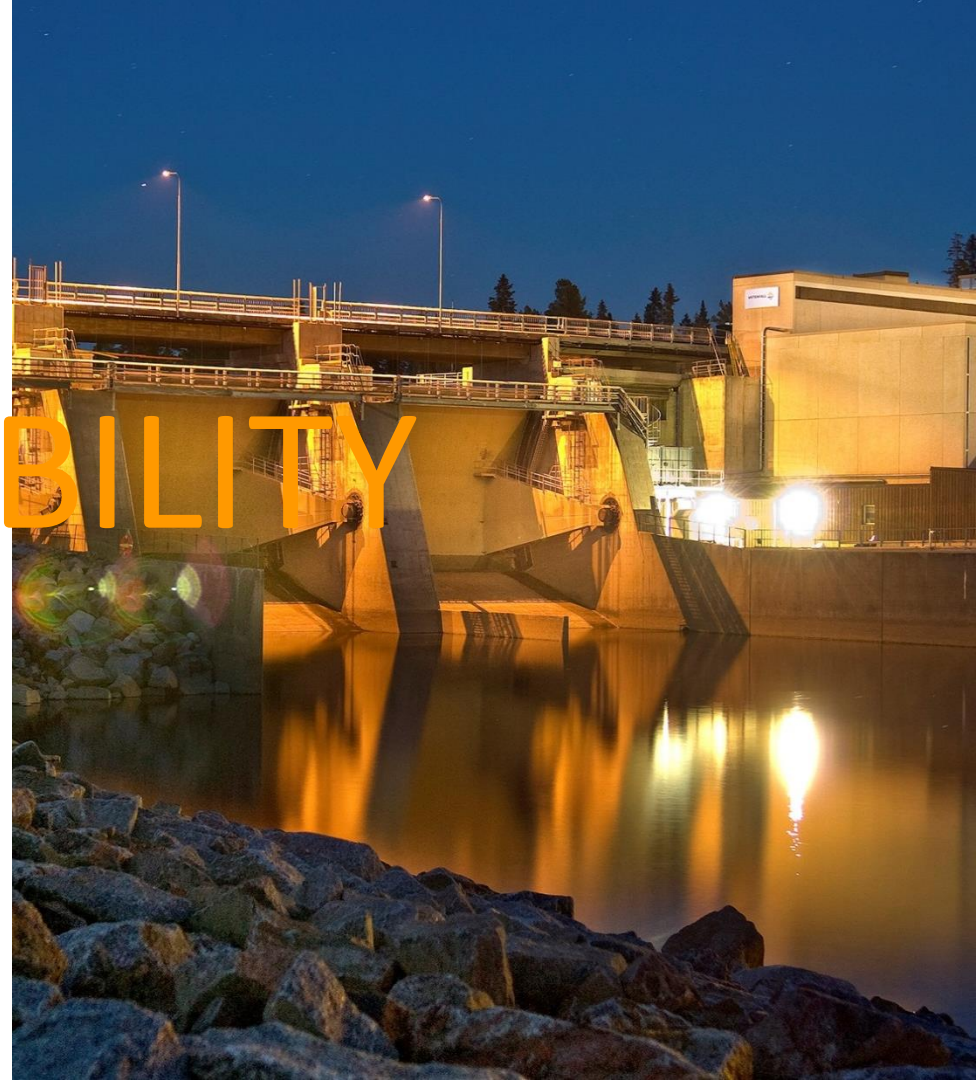
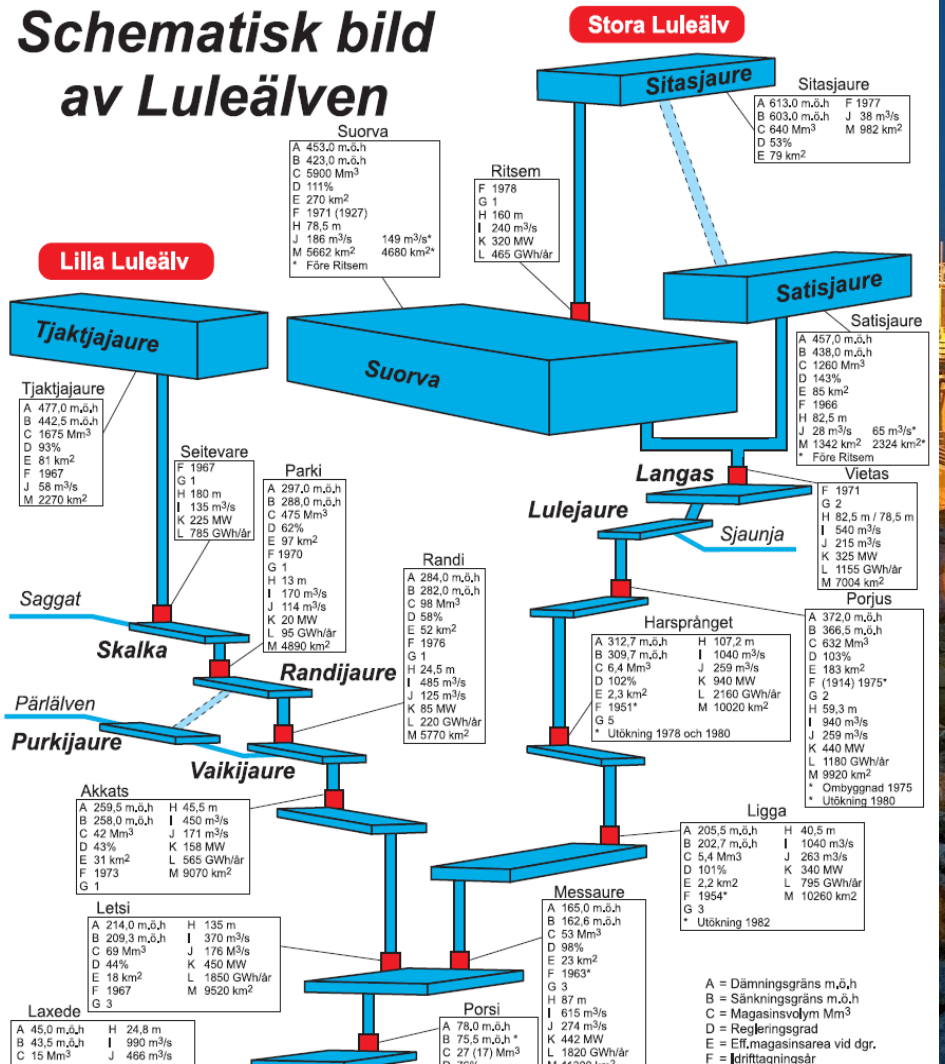
FLEXIBILITY



FLEXIBILITY



Schematisk bild av Luleälven



Who balances Nordic wind power?

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BALANCING WHAT EXACTLY?

Focus

- Balancing wind power production…
- Balancing consumption…
- Balancing residual load ☺
  (= consumption – wind generation)…

…in the Nordic syncronous area of the European electric power system.

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BALANCING WHAT EXACTLY?

Focus

- Balancing wind power production…
- Balancing consumption…
- Balancing residual load ☺
  (= consumption – wind generation)…

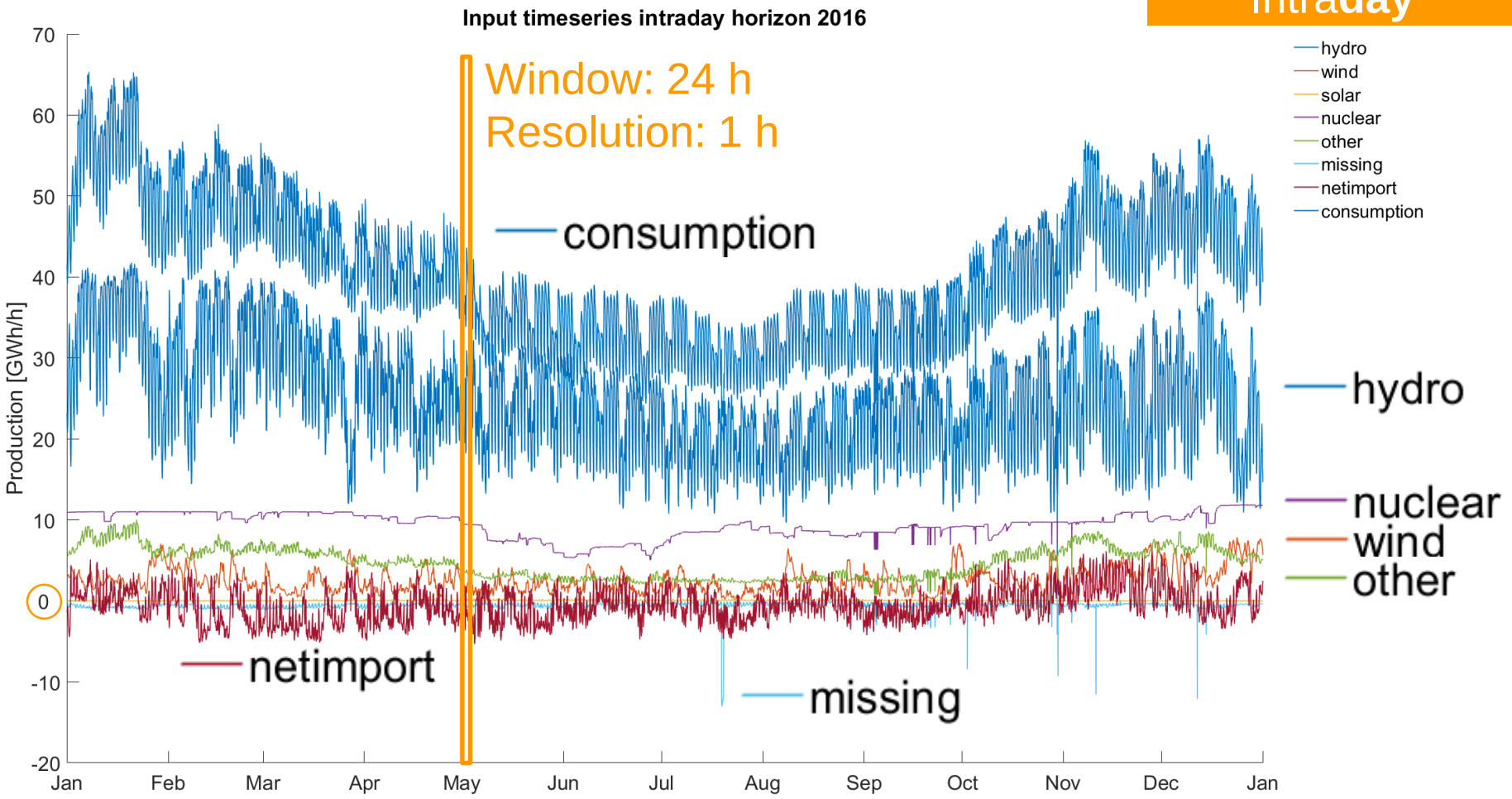
…in the Nordic syncronous area of the European electric power system.

Indata

- Time series production, consumption, exchange.
- Hourly resolution.
- Years 2015 and 2016.
- Source: Entso-E's Transparency Platform, Nord Pool, Svenska kraftnät.

METHOD

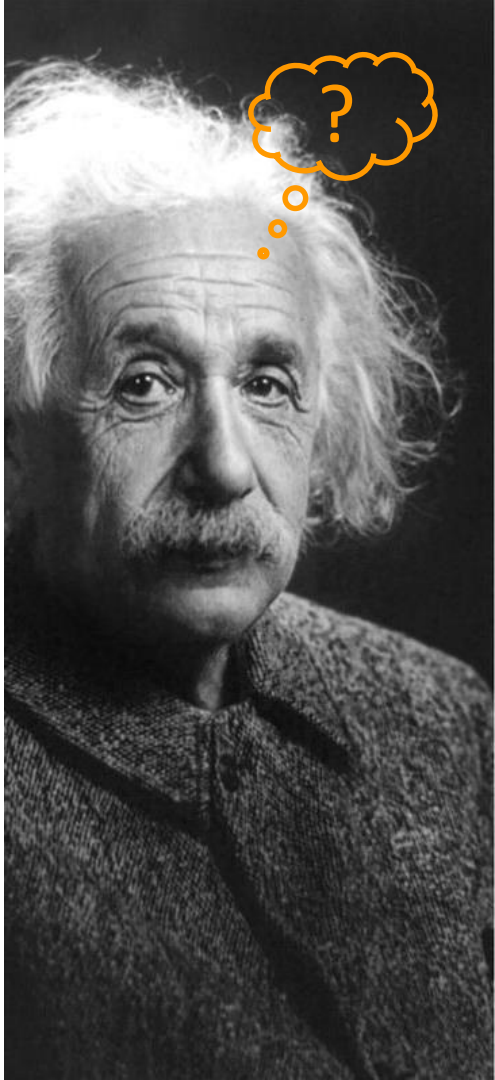
Who balances Nordic wind power?


Input timeseries intraday horizon 2016
Window: 24 h
Resolution: 1 h
consumption
netimport
missing
hydro
nuclear
wind
other
Production [GWh/h]
70
60
50
40
30
20
10
0
-10
-20
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
hydro
wind
solar
nuclear
other
missing
netimport
consumption

BALANCING CONTRIBUTION

= COV [X, -Y] / VAR [Y]

- X: Time series X per type per price area.
  ***Balancing resource**, for example hydro power production.*
- Y: Time series Y for Nordic synchronous system.
  ***To be balanced**, for example residual load, wind power production or consumption.*



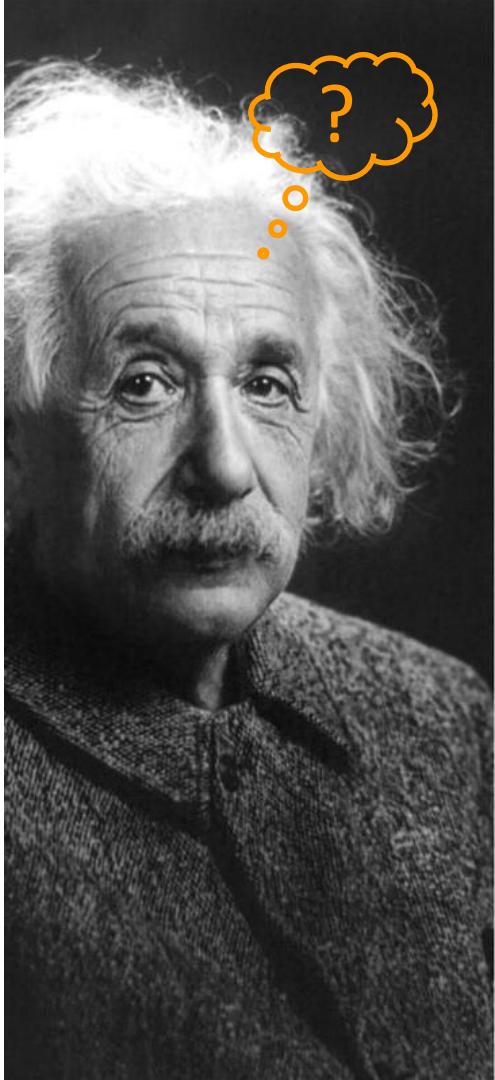
Picture: web.

VATTENFALL

BALANCING CONTRIBUTION

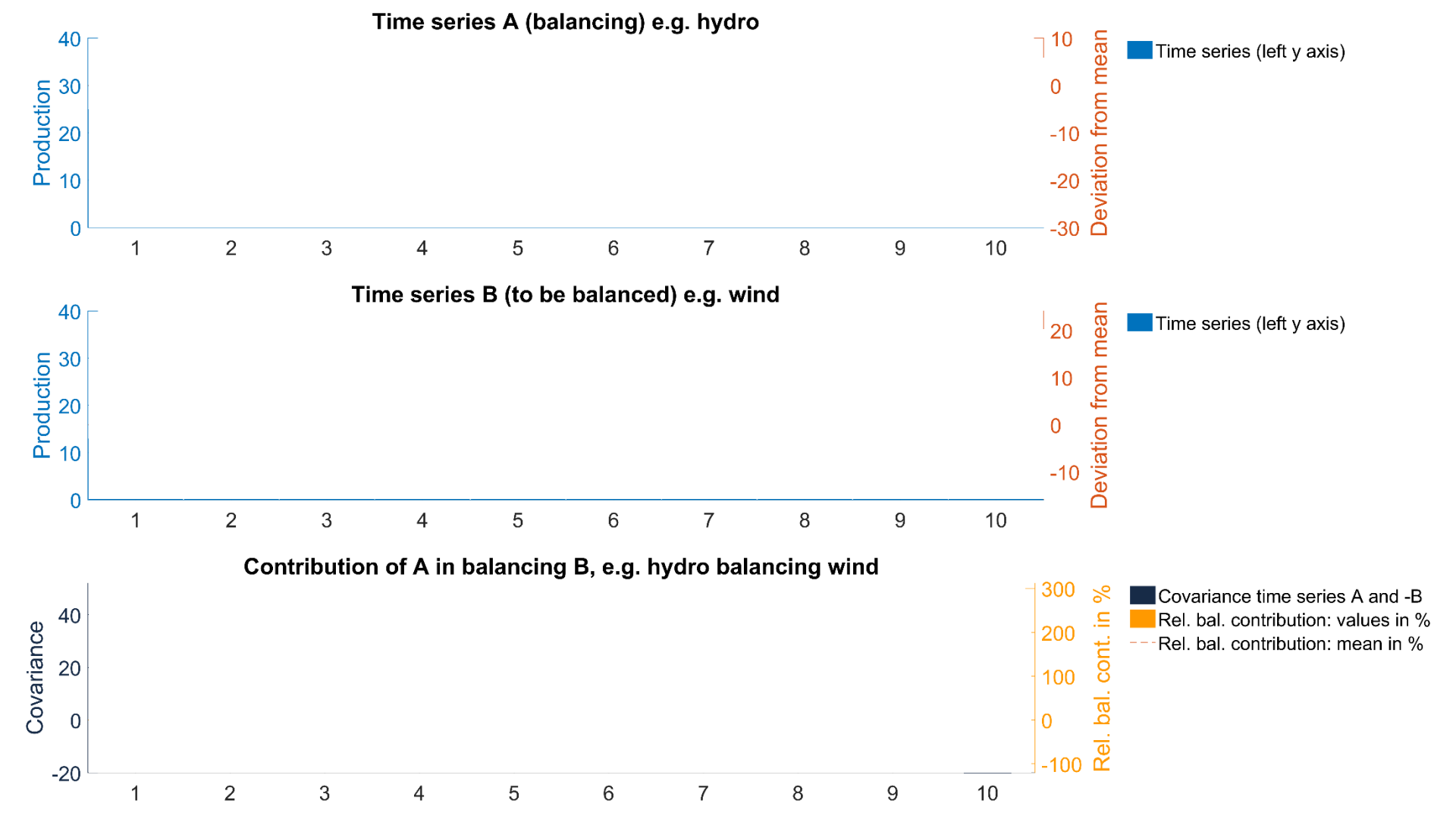
= COV [X, -Y] / VAR [Y]

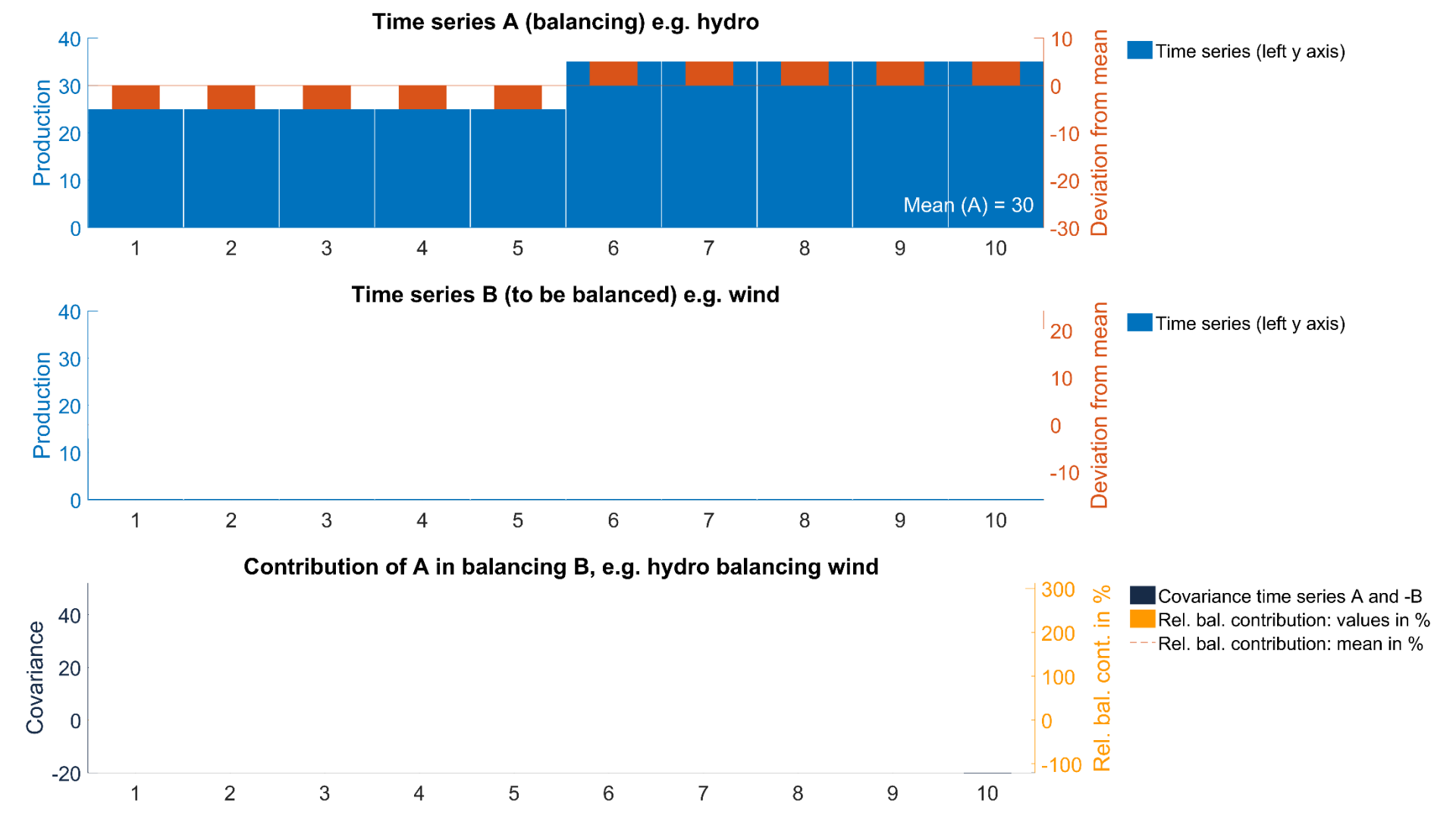
- X: Time series X per type per price area.
  ***Balancing resource**, for example hydro power production.*
- Y: Time series Y for Nordic synchronous system.
  ***To be balanced**, for example residual load, wind power production or consumption.*
- Calculated for different **time horizons**.
- Measure is **linear**, based on energy balance.
- Report: Lönnberg/Bladh 2016, Länk till PDF.

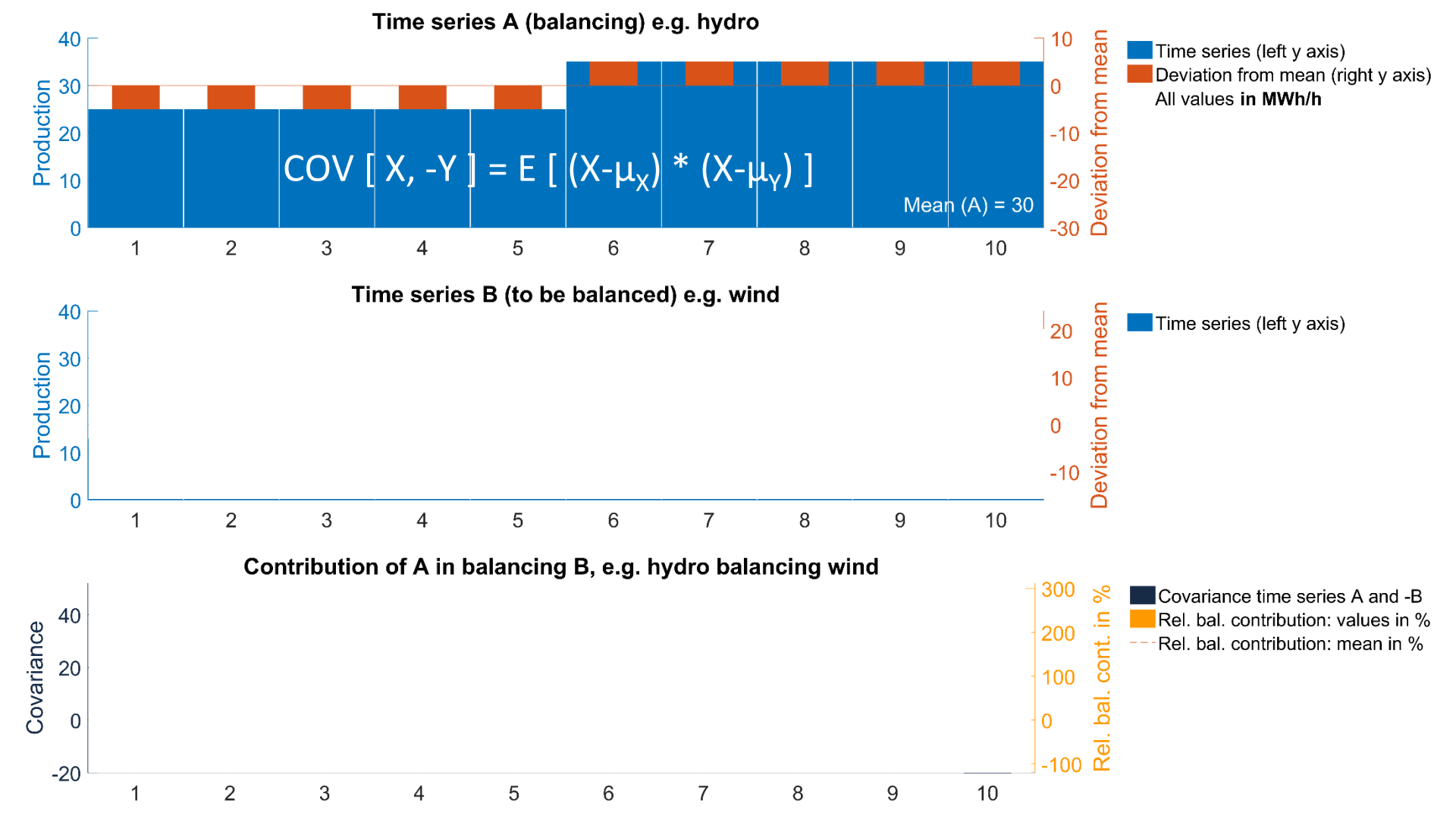


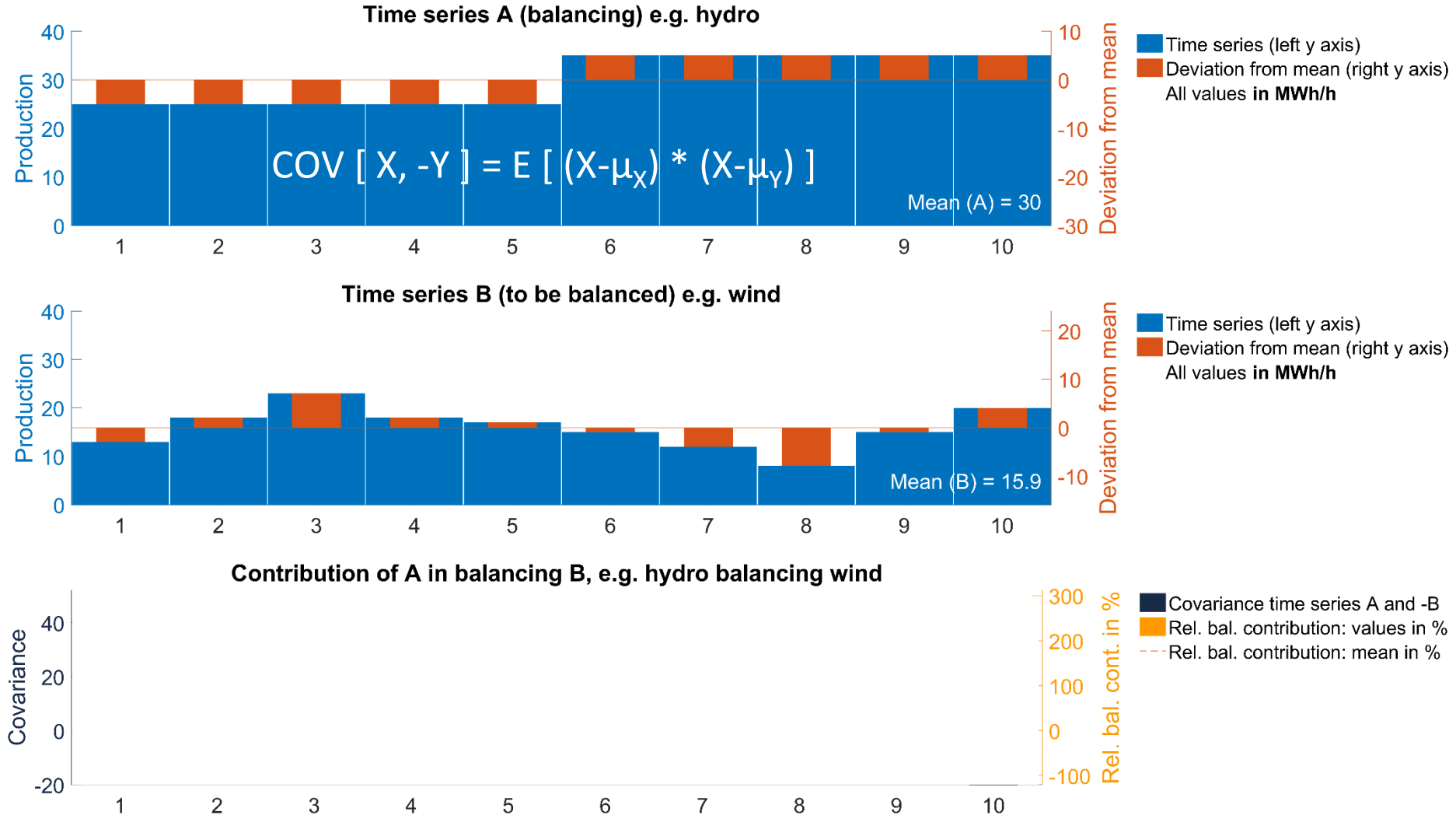
Picture: web.

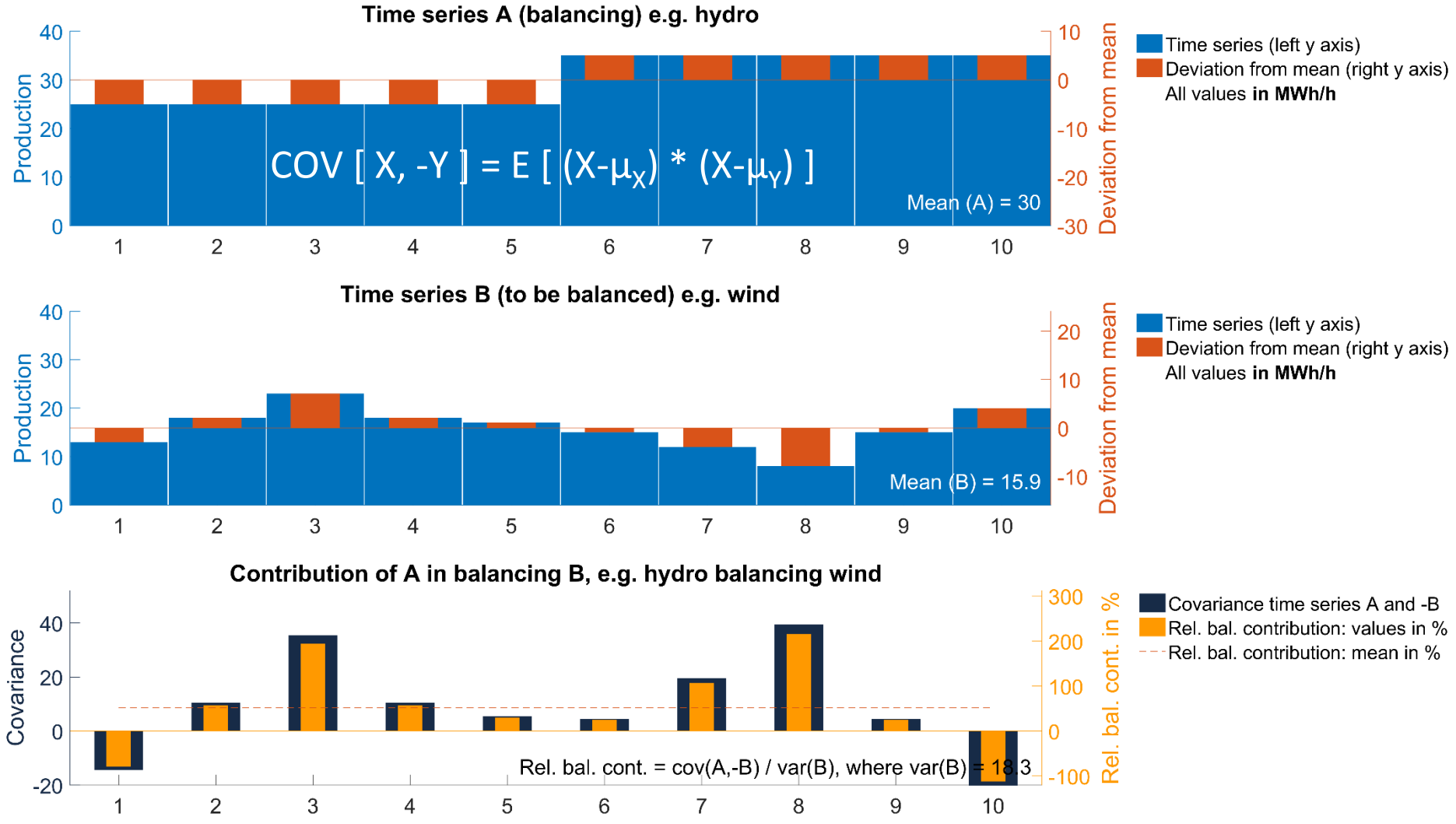
VATTENFALL

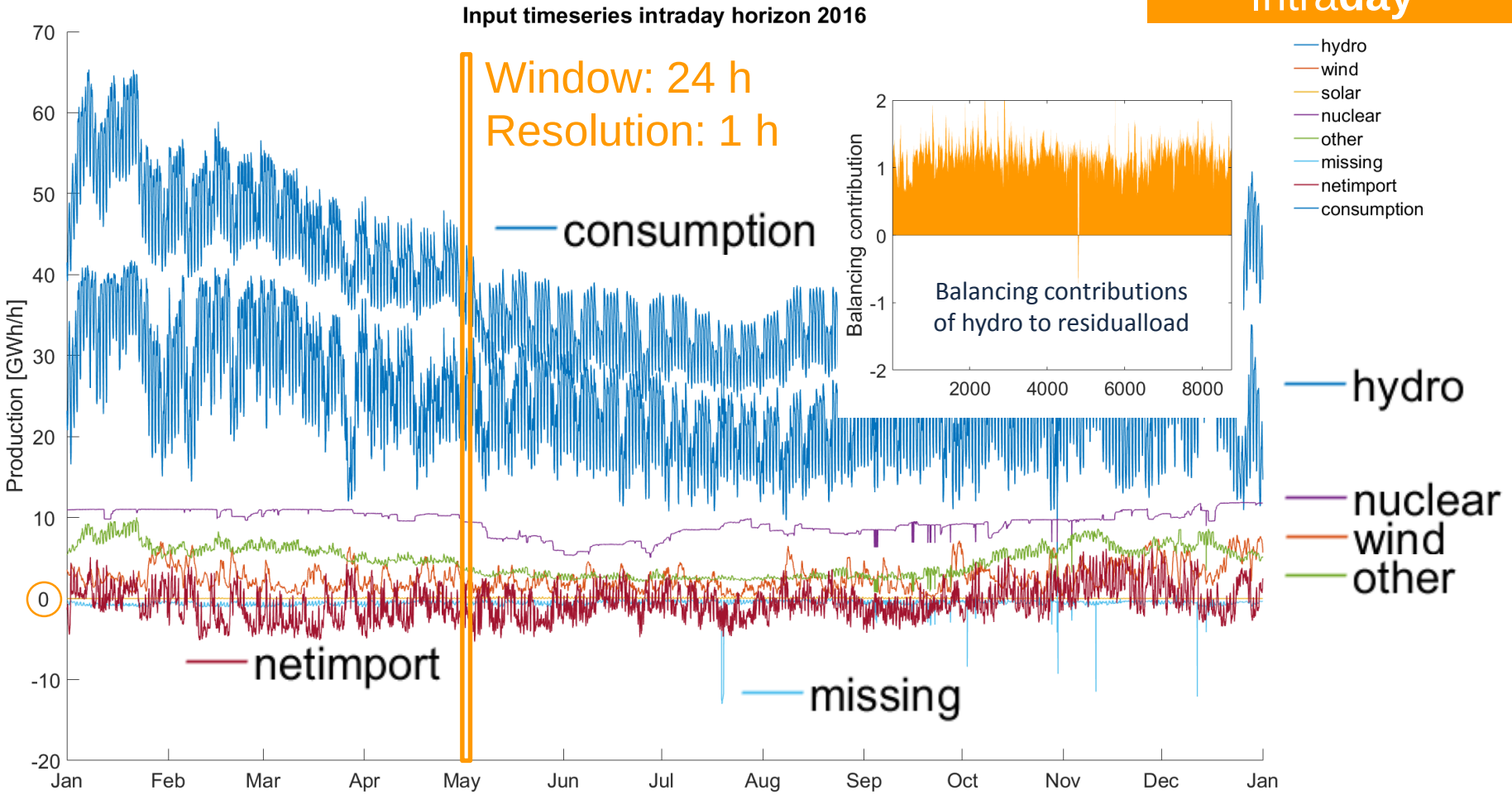

Time series A (balancing) e.g. hydro
Production
Deviation from mean
Time series (left y axis)
Time series B (to be balanced) e.g. wind
Production
Deviation from mean
Time series (left y axis)
Contribution of A in balancing B, e.g. hydro balancing wind
Covariance
Rel. bal. cont. in %
Covariance time series A and -B
Rel. bal. contribution: values in %
Rel. bal. contribution: mean in %


Time series A (balancing) e.g. hydro
Production
Deviation from mean
Mean (A) = 30
Time series (left y axis)
Time series B (to be balanced) e.g. wind
Production
Deviation from mean
Time series (left y axis)
Contribution of A in balancing B, e.g. hydro balancing wind
Covariance
Rel. bal. cont. in %
Covariance time series A and -B
Rel. bal. contribution: values in %
Rel. bal. contribution: mean in %

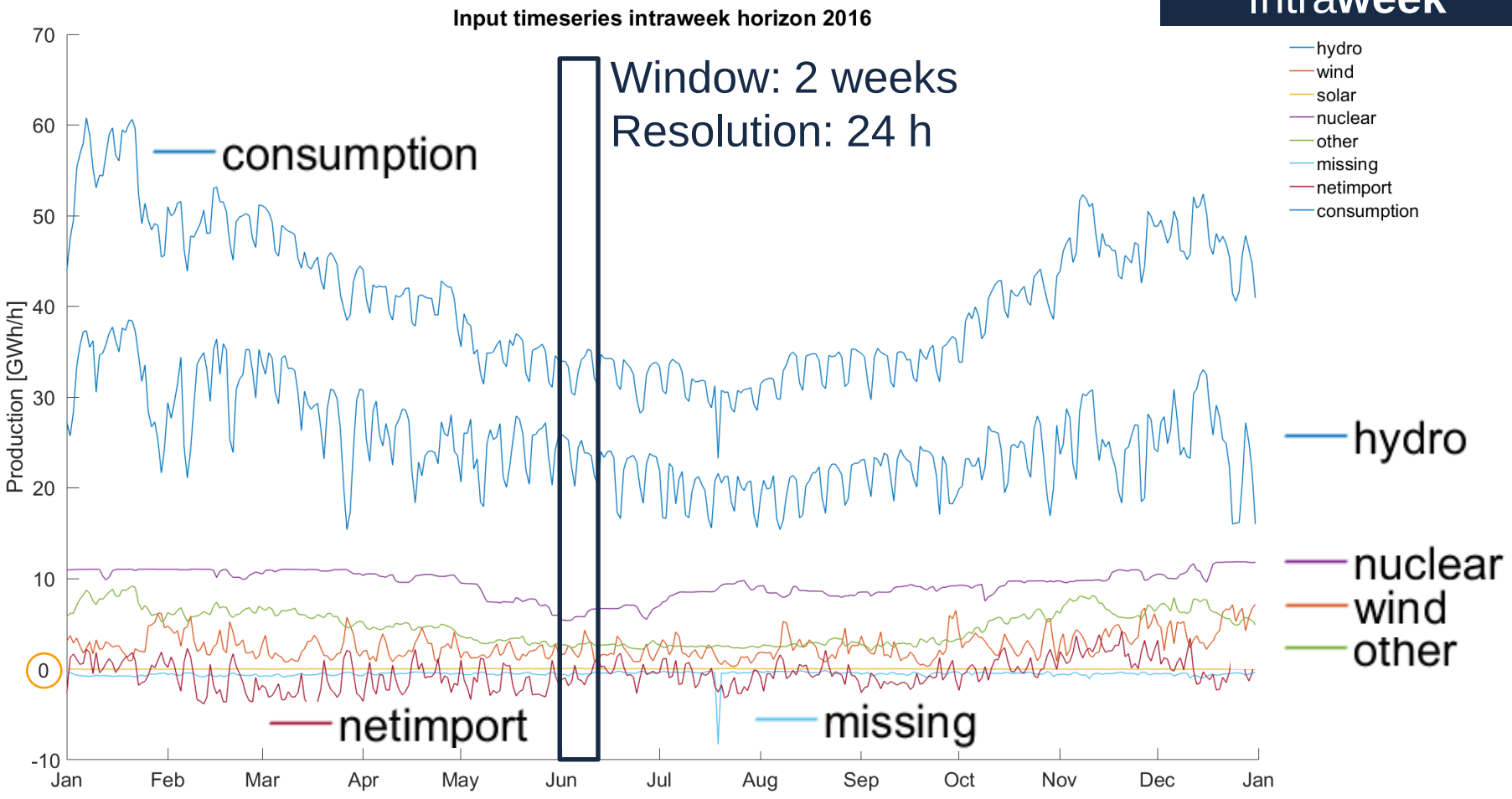

Time series A (balancing) e.g. hydro
Production
Deviation from mean
Time series (left y axis)
Deviation from mean (right y axis)
All values in MWh/h
COV [X, -Y] = E [(X-μX) * (X-μY)]
Mean (A) = 30
Time series B (to be balanced) e.g. wind
Production
Deviation from mean
Time series (left y axis)
Contribution of A in balancing B, e.g. hydro balancing wind
Covariance
Rel. bal. cont. in %
Covariance time series A and -B
Rel. bal. contribution: values in %
Rel. bal. contribution: mean in %


Time series A (balancing) e.g. hydro
Production
Deviation from mean
COV [X, -Y] = E [(X-μX) * (X-μY)]
Mean (A) = 30
Time series (left y axis)
Deviation from mean (right y axis)
All values in MWh/h
Time series B (to be balanced) e.g. wind
Mean (B) = 15.9
Contribution of A in balancing B, e.g. hydro balancing wind
Covariance
Rel. bal. cont. in %
Covariance time series A and -B
Rel. bal. contribution: values in %
Rel. bal. contribution: mean in %

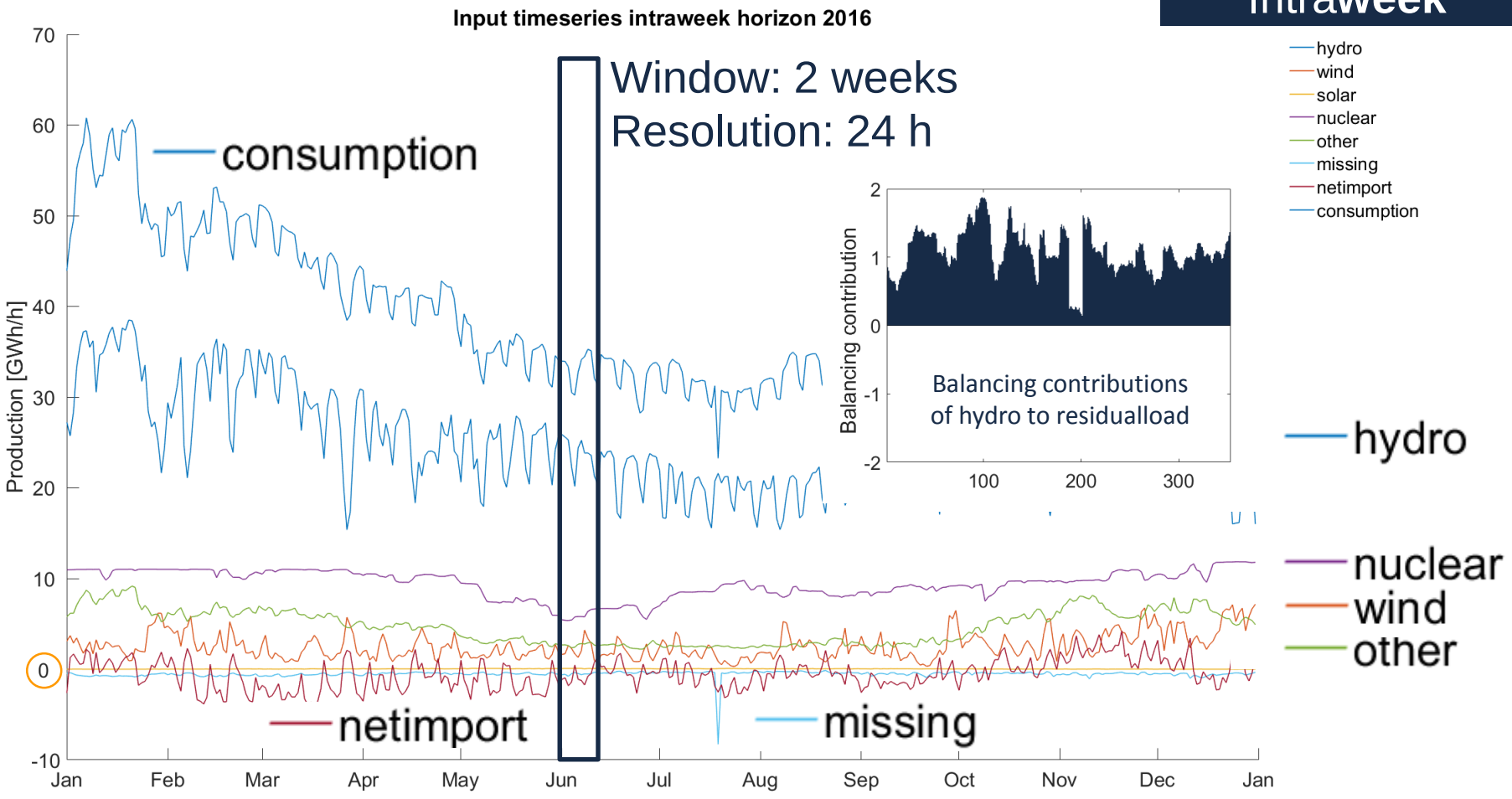

Time series A (balancing) e.g. hydro
Production
Deviation from mean
COV [X, -Y] = E [(X-μX) * (X-μY)]
Mean (A) = 30
Time series (left y axis)
Deviation from mean (right y axis)
All values in MWh/h
Time series B (to be balanced) e.g. wind
Mean (B) = 15.9
Contribution of A in balancing B, e.g. hydro balancing wind
Covariance
Rel. bal. cont. in %
Rel. bal. cont. = cov(A,-B) / var(B), where var(B) = 18.3
Covariance time series A and -B
Rel. bal. contribution: values in %
Rel. bal. contribution: mean in %


Input timeseries intraday horizon 2016
Window: 24 h
Resolution: 1 h
consumption
netimport
missing
hydro
nuclear
wind
other
Production [GWh/h]
70
60
50
40
30
20
10
0
-10
-20
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Balancing contribution
2
1
0
-1
-2
2000
4000
6000
8000
Balancing contributions
of hydro to residualload
hydro
wind
solar
nuclear
other
missing
netimport
consumption

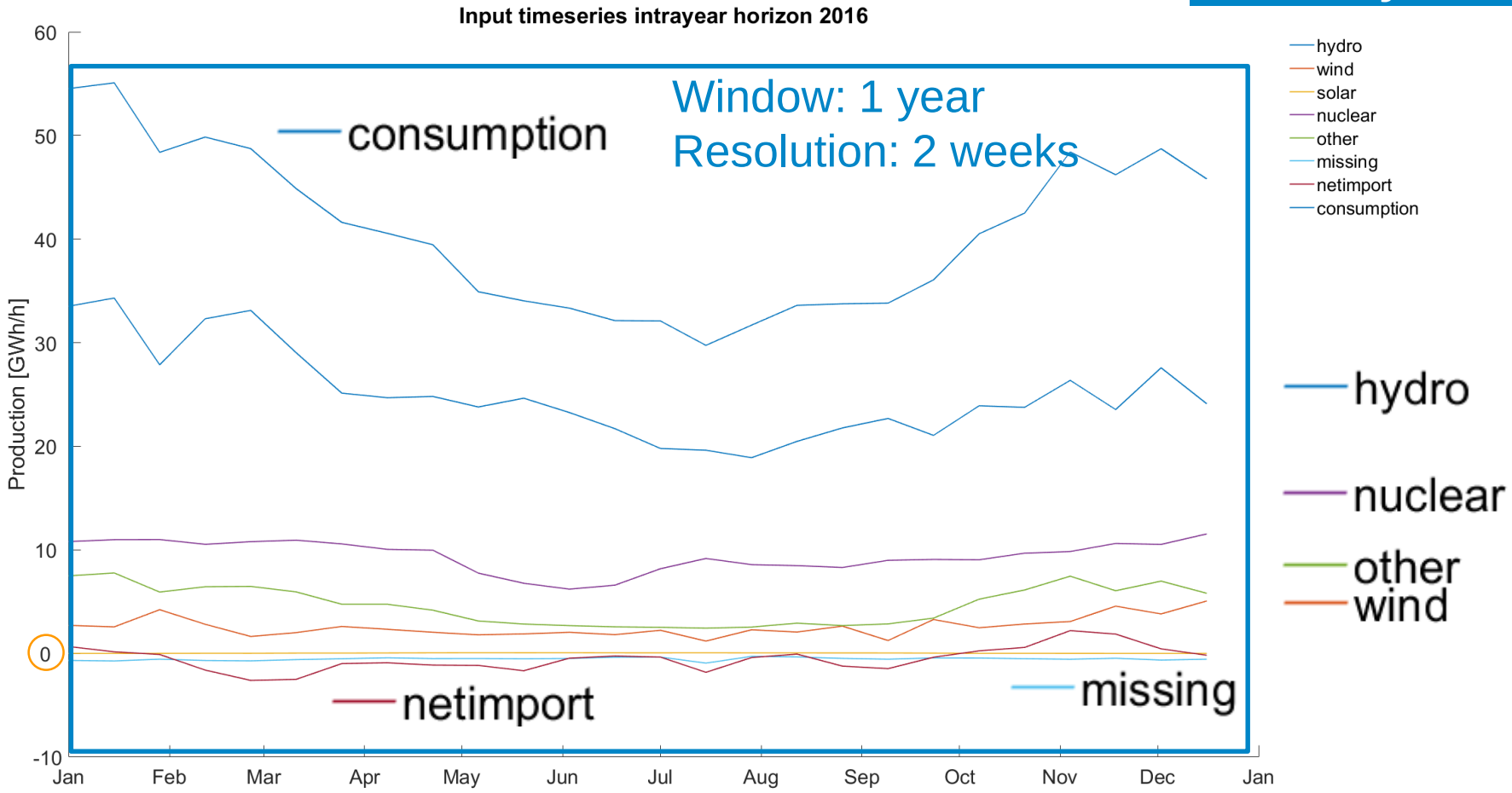
Intraweek

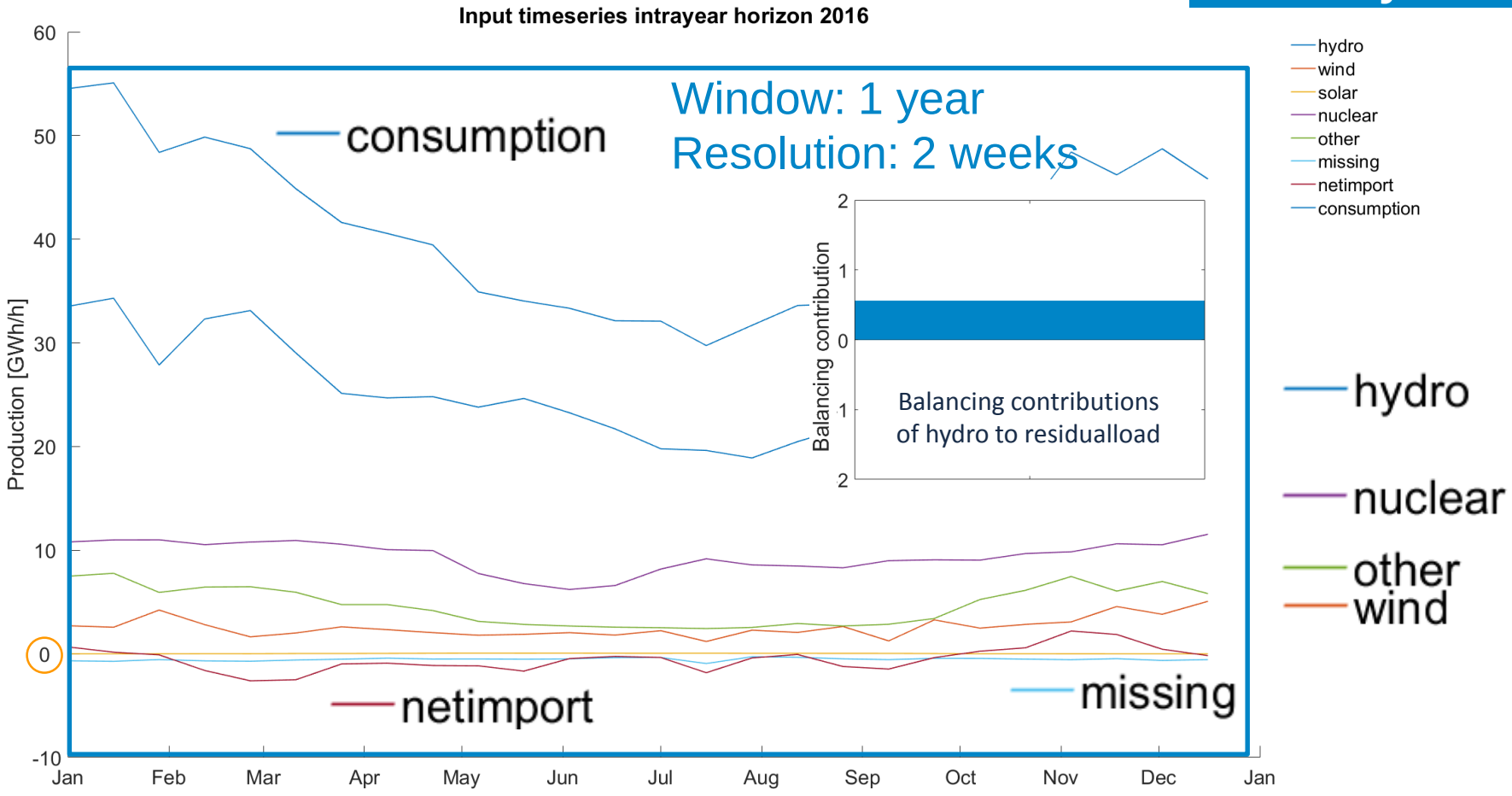

Input timeseries intraweek horizon 2016
Window: 2 weeks
Resolution: 24 h
consumption
netimport
missing
hydro
nuclear
wind
other
Production [GWh/h]
70
60
50
40
30
20
10
0
-10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
hydro
wind
solar
nuclear
other
missing
netimport
consumption

Intraweek


Input timeseries intraweek horizon 2016
Window: 2 weeks
Resolution: 24 h
consumption
netimport
missing
hydro
nuclear
wind
other
Production [GWh/h]
70
60
50
40
30
20
10
0
-10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Balancing contribution
2
1
0
-1
-2
100
200
300
Balancing contributions
of hydro to residualload
hydro
wind
solar
nuclear
other
missing
netimport
consumption

Intrayear


Input timeseries intrayear horizon 2016
Production [GWh/h]
60
50
40
30
20
10
0
-10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
consumption
Window: 1 year
Resolution: 2 weeks
netimport
missing
hydro
wind
solar
nuclear
other
missing
netimport
consumption
hydro
nuclear
other
wind


Input timeseries intrayear horizon 2016
Window: 1 year
Resolution: 2 weeks
consumption
netimport
missing
Production [GWh/h]
60
50
40
30
20
10
0
-10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Balancing contribution
2
1
0
1
2
Balancing contributions
of hydro to residualload
hydro
wind
solar
nuclear
other
missing
netimport
consumption
hydro
nuclear
other
wind

INSIGHTS

Who balances Nordic wind power?

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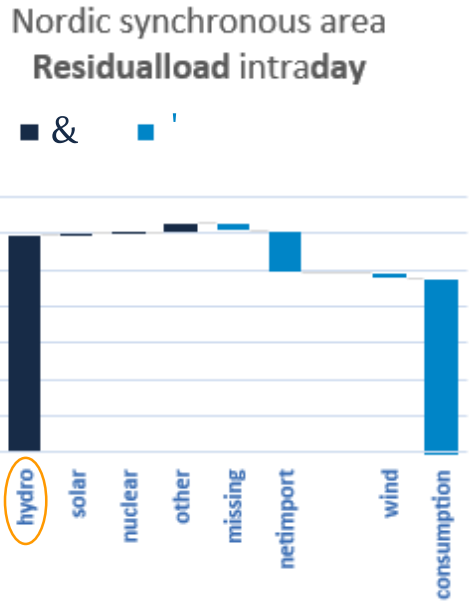
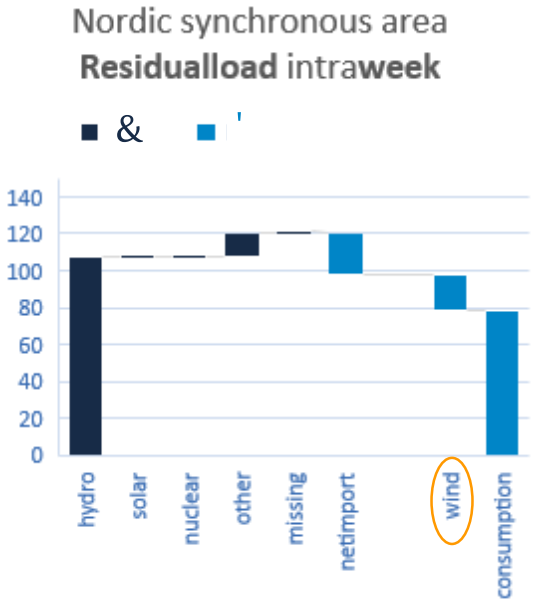
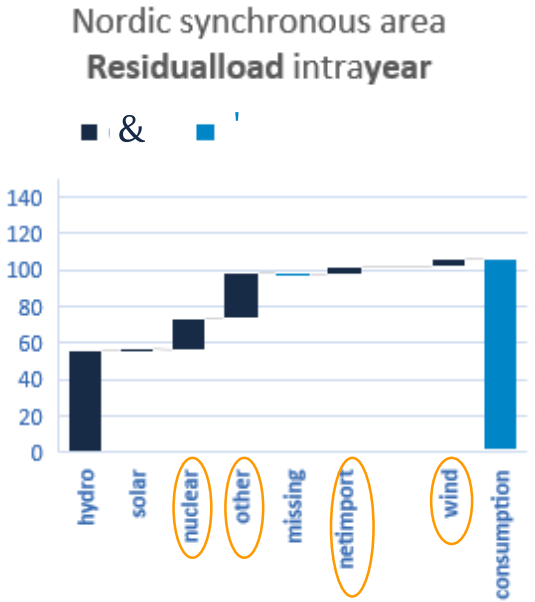
SOME RESULTS

Residualload (t) = consumption (t) – wind (t)

Balancing contribution in %







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TAKEAWAYS

- **Ex-post assessment** of production planning.
  Main limitation: no insights about potential balancing contributions. §
- So far, **too little wind power** capacity to see effects on residualload. One- to two-week patterns are challenging.
- **Patterns** (time horizons, zone and focus ”Y”) differ and indicate **change**s. How can we prepare ourselves for that?
- Hydro power is an important balancing resource, but might be **complemented** and **used differently** in the future.
- **Interconnectors**, **solar** power and **consumption** are promising with regard to balancing contribtions.

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TACK!

Critical feed-back & comments welcome:
richard.scharff@vattenfall.com

Bild: Claas Rickert.