Methods for estimation of occurred icing losses in operational wind farms

Measurements and modeling

Results from the ProdOptimize project

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Winterwind 2016

Contents

- Presentation of ProdOptimize
- Estimation of losses using the Potential Energy Production (PEP)
- IceLoss – modeling of losses
- Nacelle based lidar and the nacelle anemometer during icing conditions

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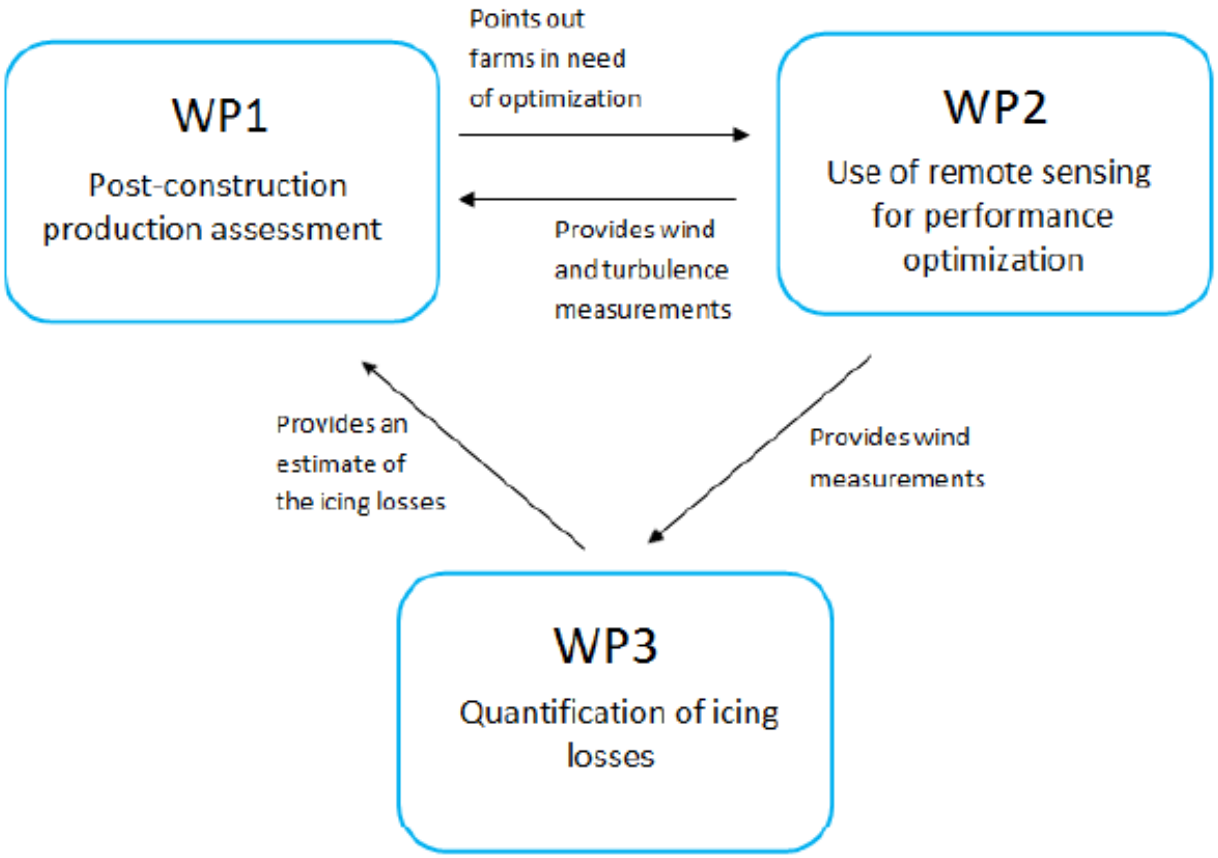
ProdOptimize

Assessment and optimization of the energy production of operational wind farms



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ProdOptimize

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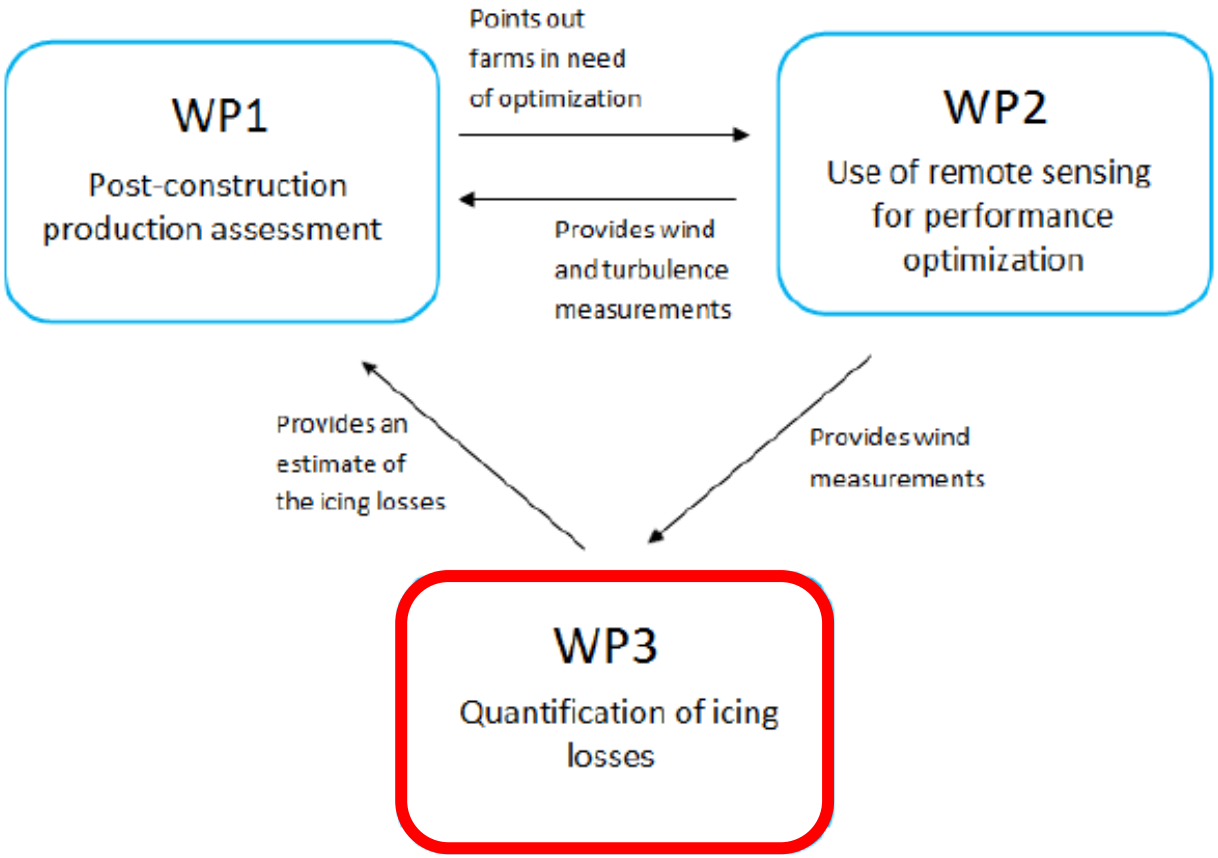

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Definitions

Full performance = no alarm, curtailment, icing etc.

PEP – Potential energy production

Loss = SUM(PEP – Actual production)

Sum over all instances
when WTG is not running in
full performance

$$\text{Relative Loss} = \frac{\textbf{Loss}}{\text{Actual production} + \textbf{Loss}}$$

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Methods to assess experienced non-full performance losses. PEP - Potential Energy Production

WIND SPEED AND HISTORICAL PC methods

PEP-PC1

Historical power curve relating the nacelle anemometer wind speed and the produced power

PEP-PC2

Historical power curve relating modeled wind speed and direction to produced power

POWER BASED methods

PEP-PA

Average production of wind farm

PEP-RA

Average production of most representative neighbor turbines chosen subjectively based on proximity/terrain characteristics

PEP-PRM

Power ratio matrix

PEP-N

Production of the most representative neighbor WTG chosen objectively based on lowest historical sectorwise bias

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Methods to assess experienced non-full performance losses. PEP - Potential Energy Production

Methods outlined in IEC/TS 61400-26-2

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PEP-N

Pro… …epresentative neighbor WTG chosen obje… …lowest historical sectorwise bias

Require neighboring WTGs to be in full-performance.
Cause non-successful estimate of potential energy production when non-full performance status is affecting full park: Ice is one example

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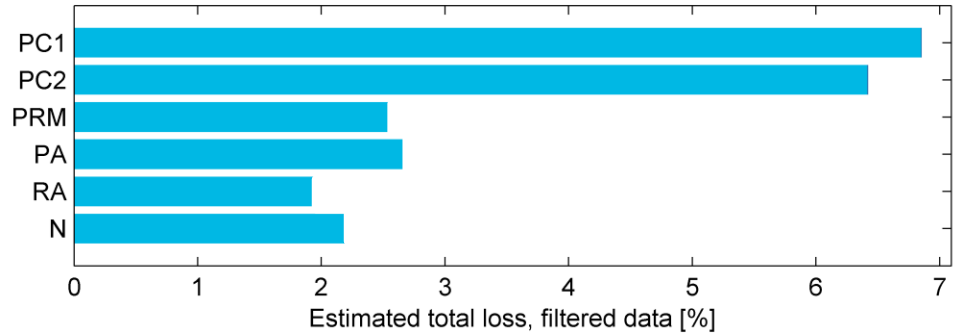
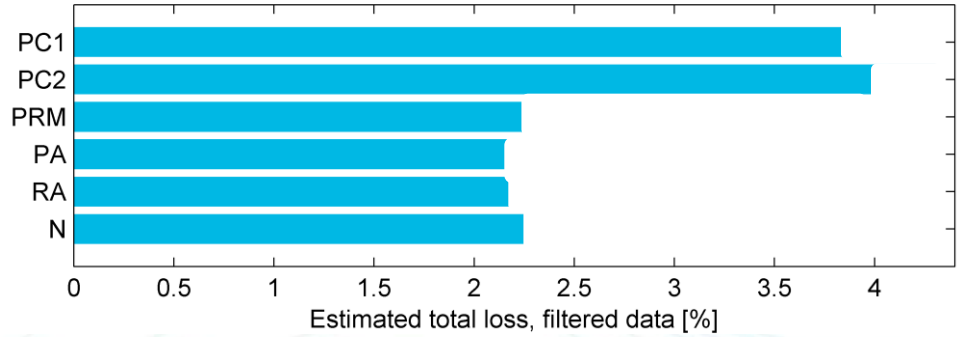
General results: Non-full performance losses

WF1 (70 months)



WF2 (24 months)



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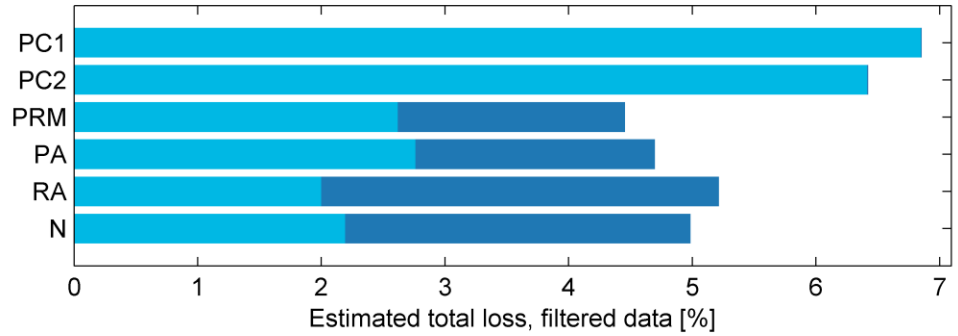
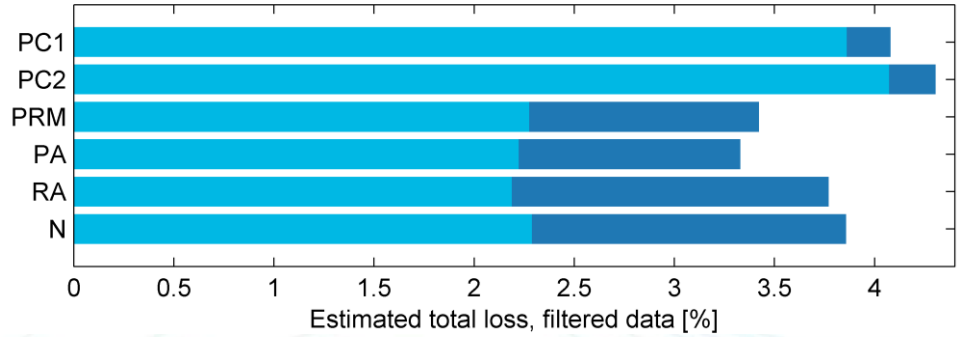


Not well suited [site specific]

Adjustment due to non-successful estimation of potential energy production

WF2 (24 months)



Not well suited [site specific]

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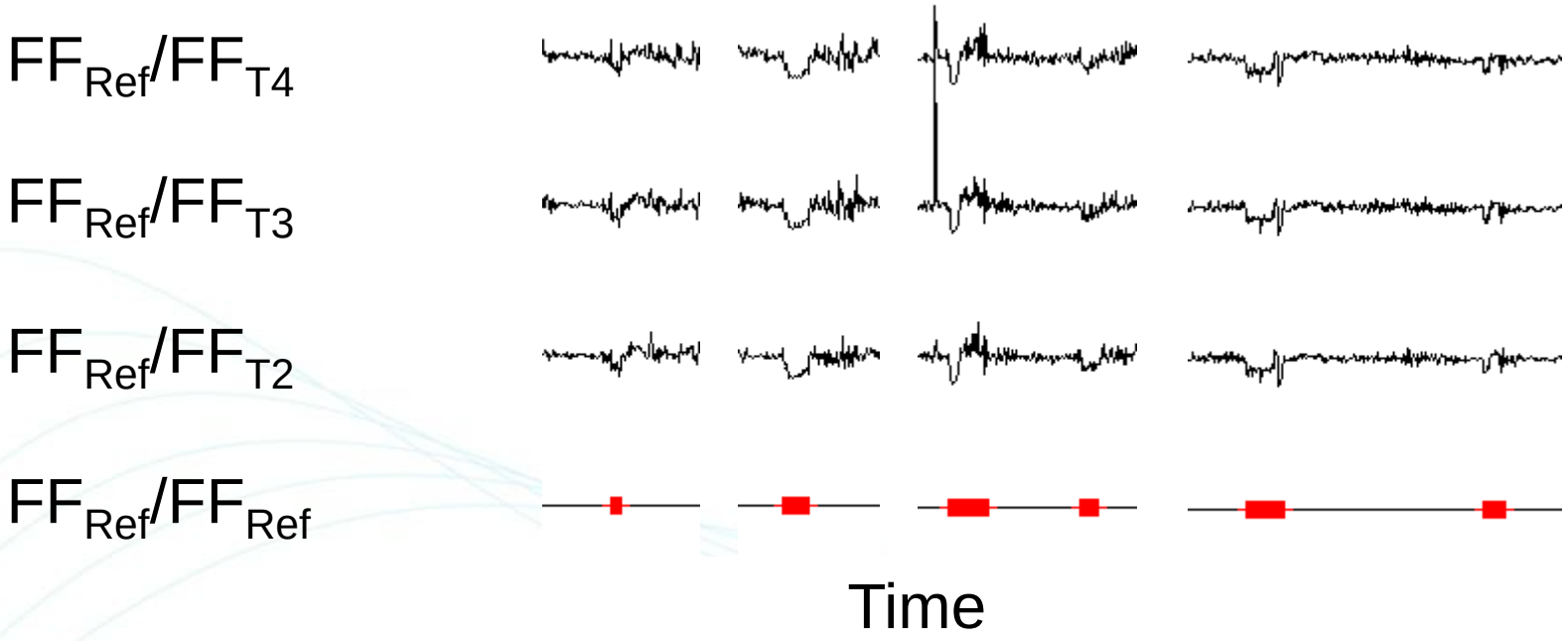
Caution when using PEP-PC1 (nacelle anemometer and specific power curve)

! The nacelle anemometer might not have the same characteristics during non-full performance and full performance periods



FF = Wind Speed

= Non-full performance period

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Caution when using PEP-PC2 (modeled wind and specific power curve)

! Need much data!

! Mean absolute error is large
- forecast errors and timing of weather events will affect the result over short periods

The bias is found to be low looking over a complete season

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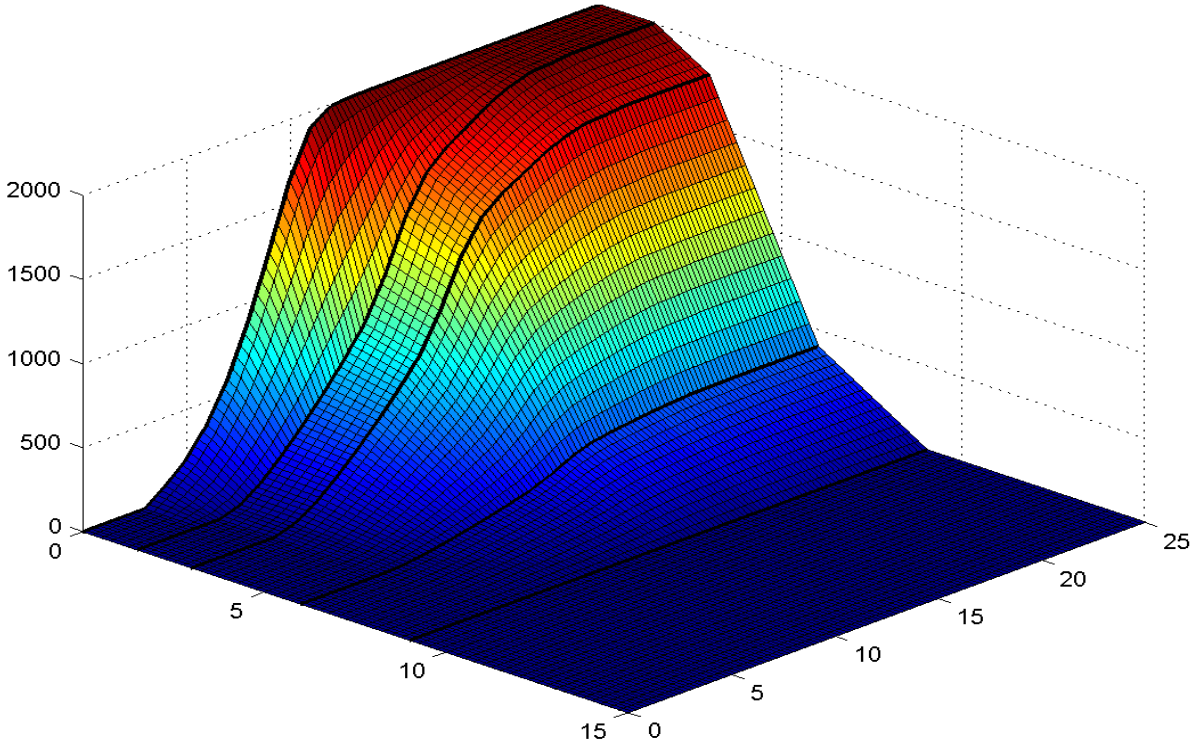
Icing losses from the IceLoss model

- Model for calculation of ice loads and losses due to the ice loads developed by Kjeller Vindteknikk

- Use data from a numerical weather prediction (NWP) model in combination with an ice accretion model



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IceLoss

- Validation is important
  - We validate the end result – it is difficult to validate the NWP-parameters with data normally available in wind power projects

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IceLoss

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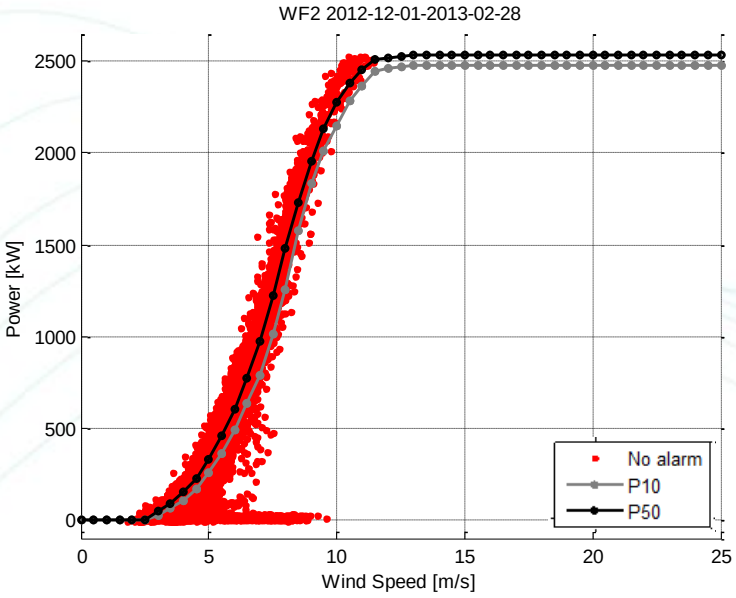
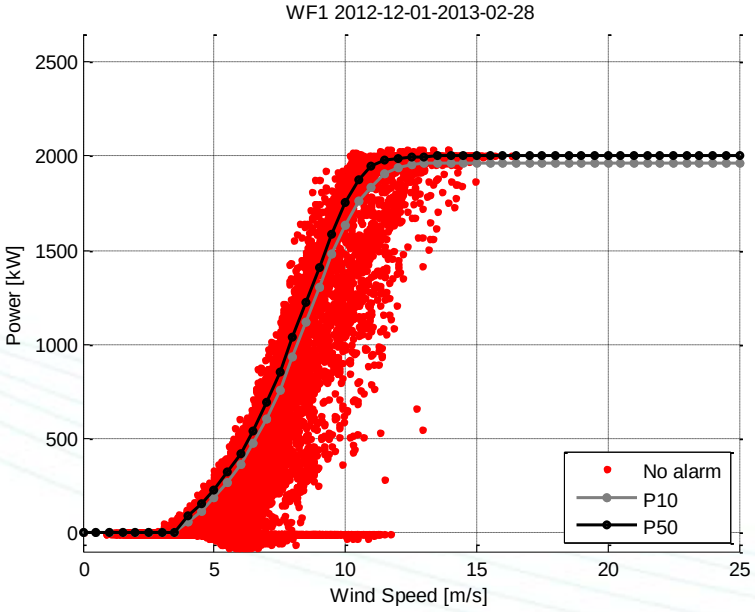
  - We validate the end result – it is difficult to validate the NWP-parameters with data normally available in wind power projects
- Compare the same things - operational strategies important to consider when validating model results





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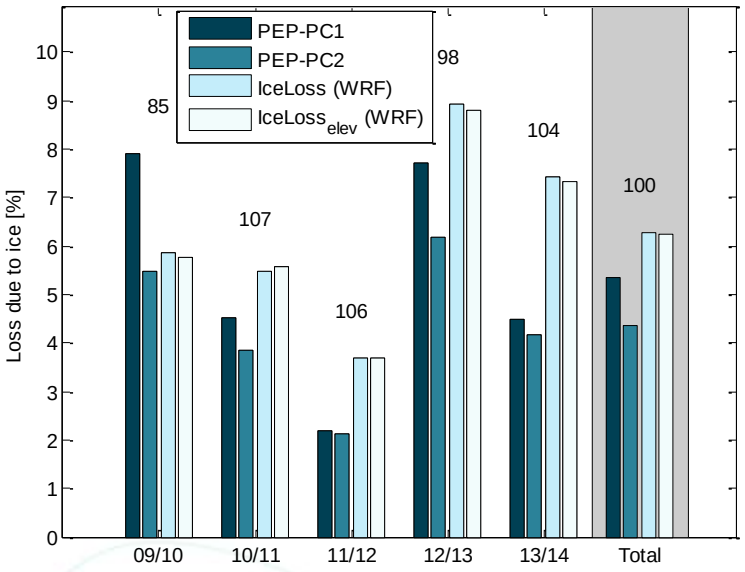
IceLoss - validation



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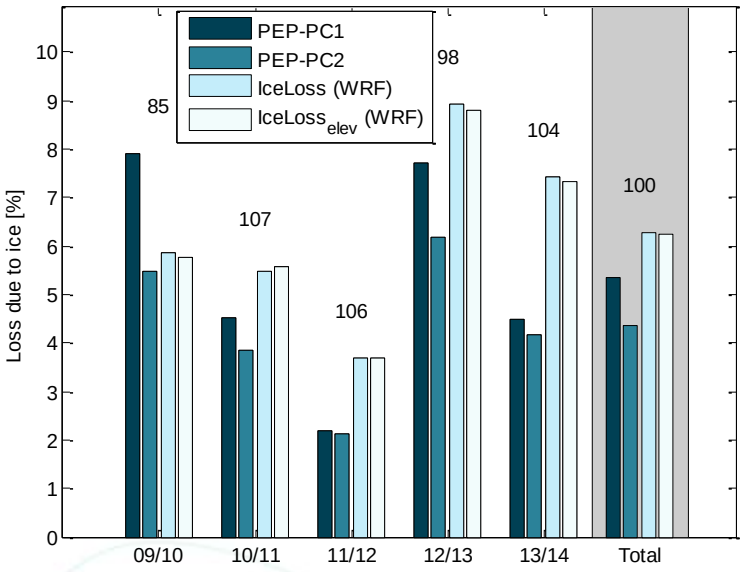

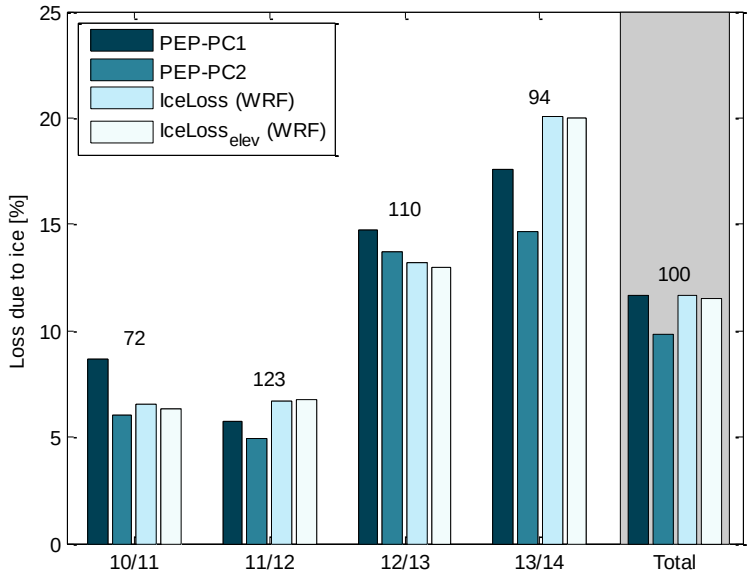

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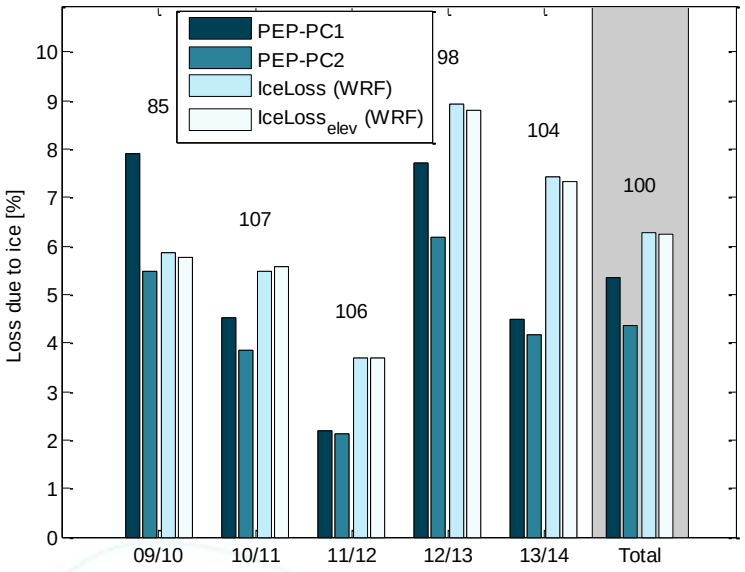

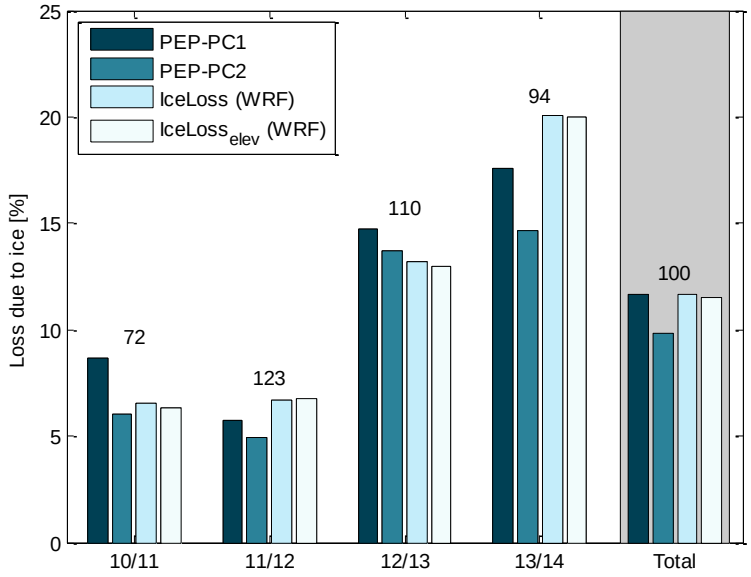

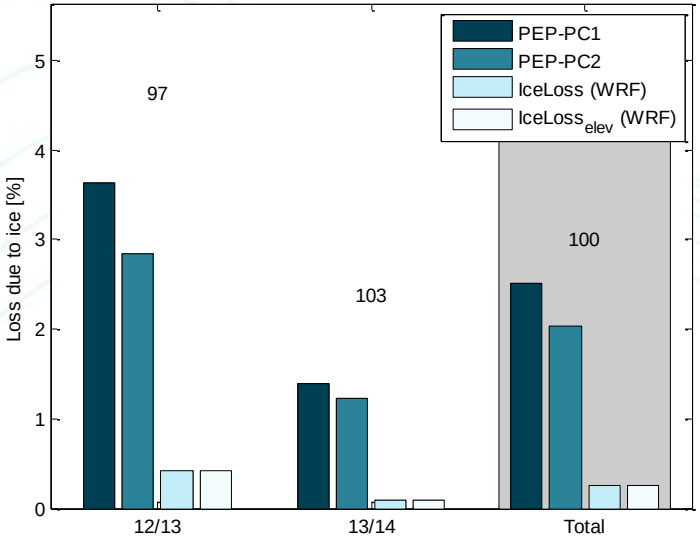

Remember the operational strategy!

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Nacelle mounted lidar in ProdOptimize

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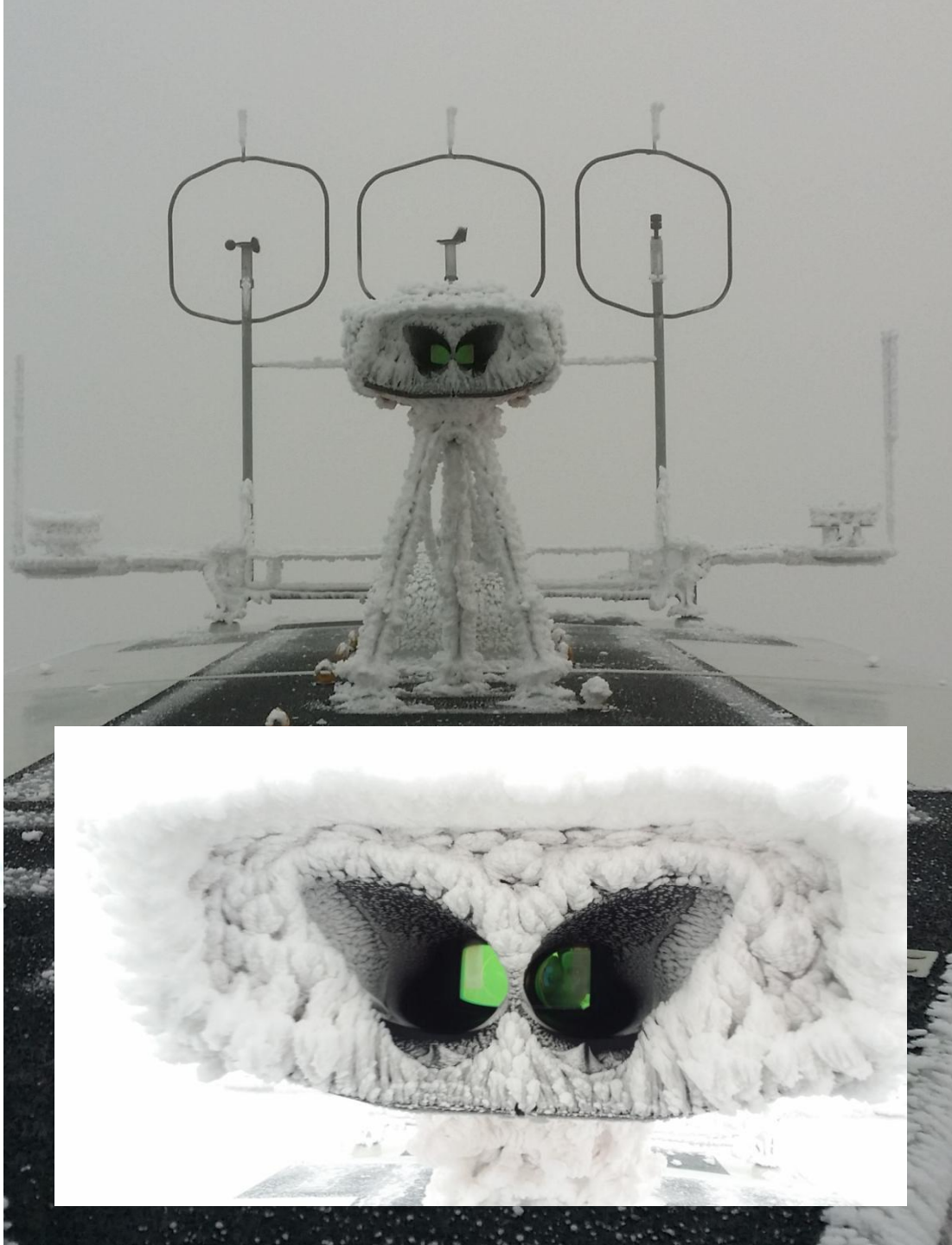
Experience

- Wind Iris
- Measurements at different turbines and wind farms since early 2014
- Generally good data availability
- Has been working well under icing conditions



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Thank you for listening!

Reports from the ProdOptimize project will be available during spring 2016 at www.vindforsk.se

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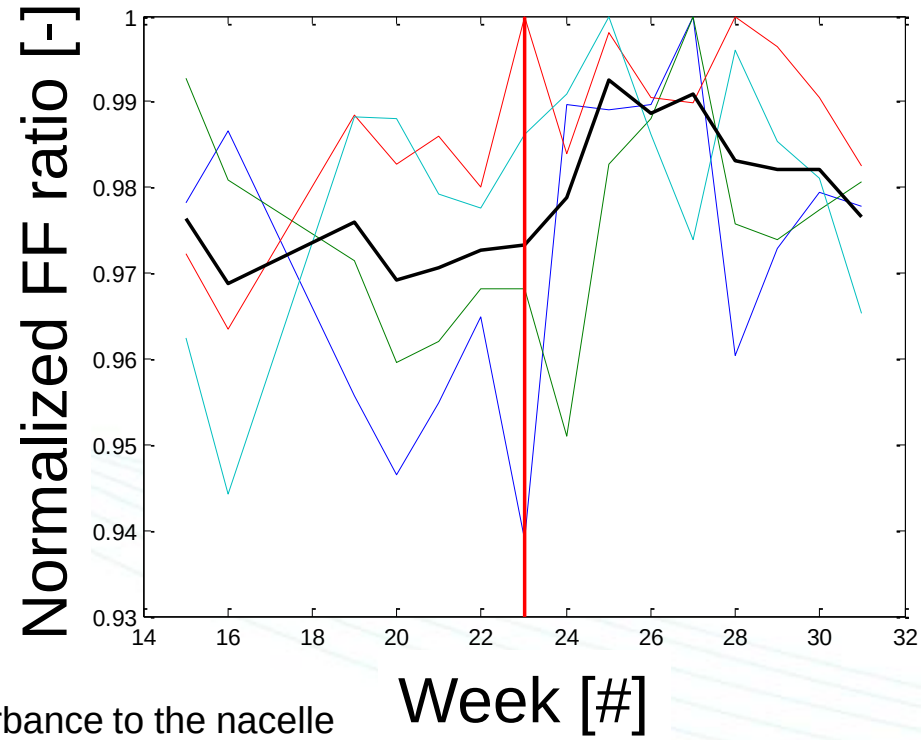
Does Wind Iris disturb the nacelle anemometer?

The WI is installed according to best practice.
Look at nacelle wind speed ratios between ”WI”-turbine and neighbouring turbines during full performance and wake free conditions.

= Dismantling date

= Individual ratio

= Mean of ratios



! The WI seems to cause a small disturbance to the nacelle anemometer.

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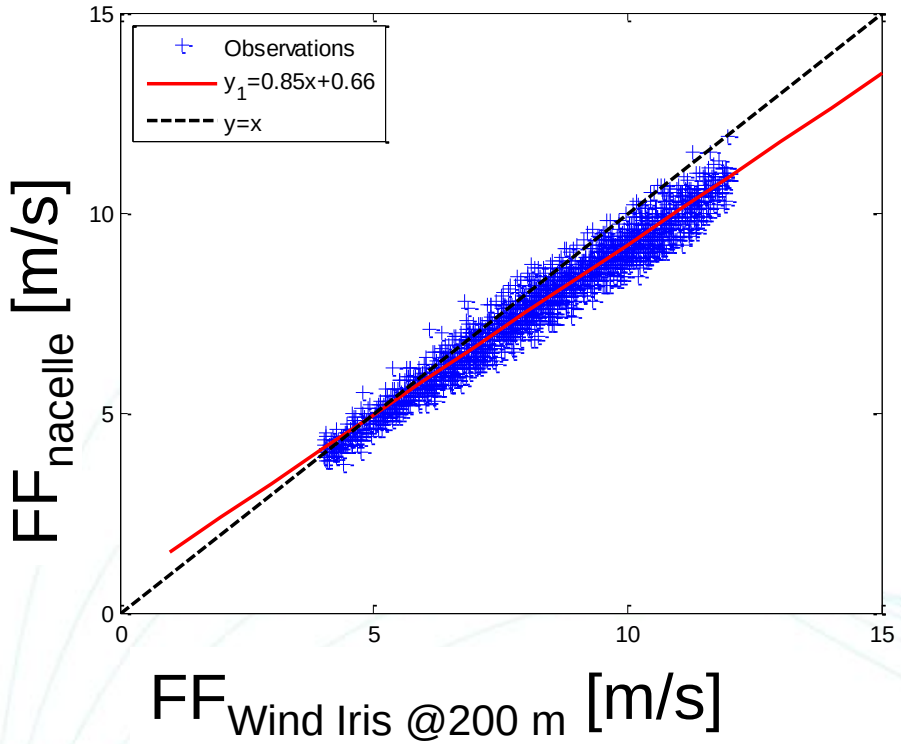
Difference in nacelle anemometer characteristics during icing and non-icing conditions

No ice, no wake



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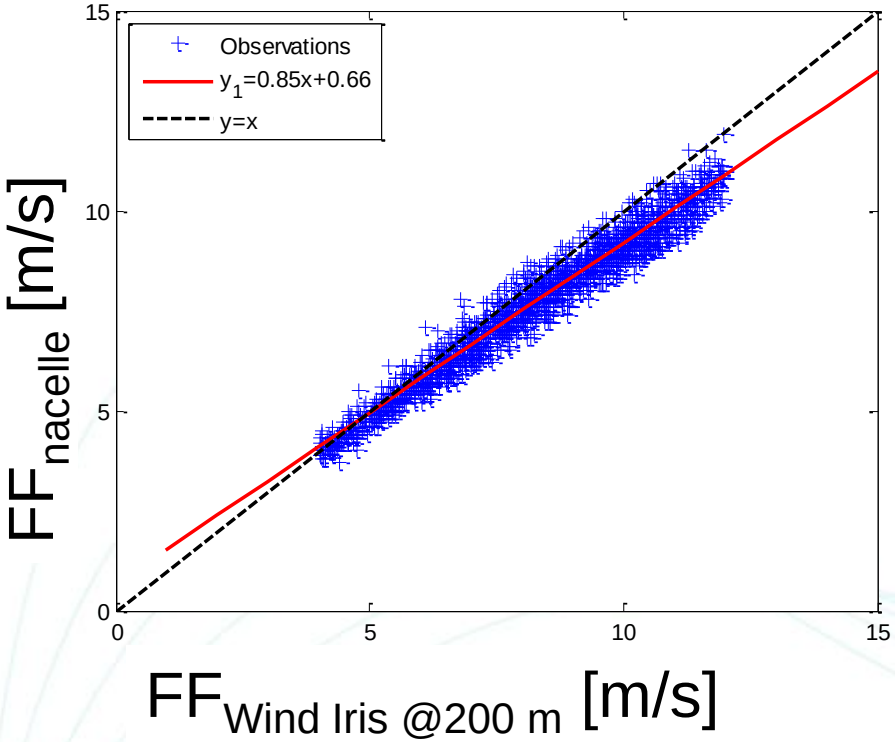

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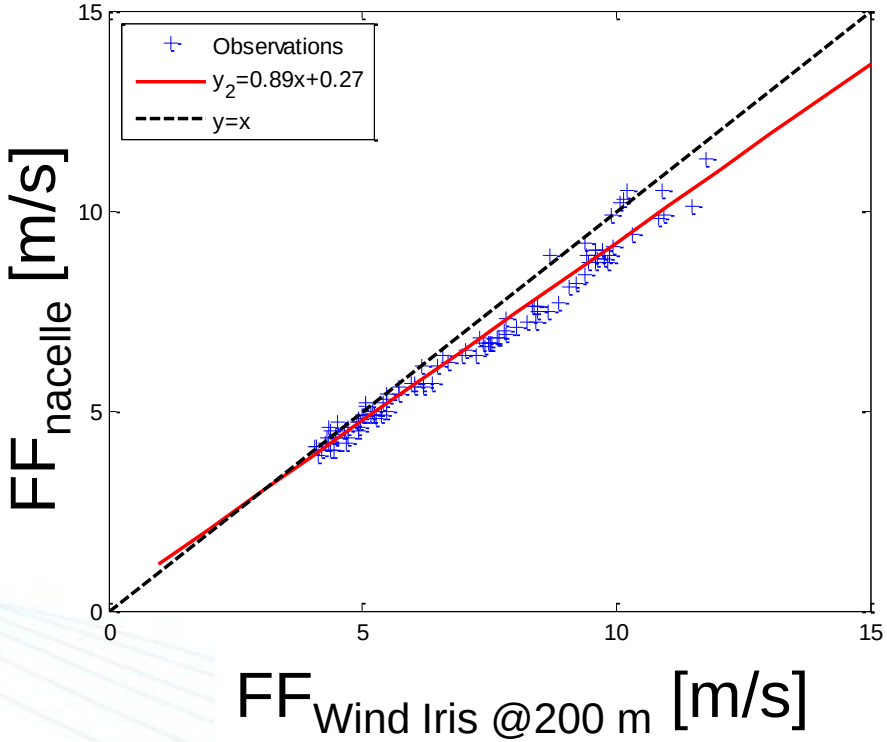

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Difference in nacelle anemometer characteristics during icing and non-icing conditions

- Large uncertainties in this comparison
  - Limited amount of iced data in the comparison
  - Different wind speed and direction distribution in the two data sets. There will be differences even if we have used only sectors when icing is found to mainly occur.
  - Different stability regimes in the two data sets that will affect
    - Turbulence
    - Shear
    - Veer
  - We need more data to be able to isolate the effect of the ice on the blades!

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Summary PEP-methods

Which methods that are most suitable for assessing experienced losses are site specific (climatological conditions, quality of data, size of the wind farm)

Name	Short name	Outlined in IEC/TS 61400-26-2	Needs historical data	Needs wind data	Relies on other WTGs in full perf.	Sensitive to conservative filtering
Historical PC, nacelle wind	**PEP-PC1**	Yes	Yes	Yes	No	No
Historical PC, modeled wind	**PEP-PC2**	No	Yes	Yes	No	No
Power ratio matrix	**PEP-PRM**	No	Yes	No	Yes	Yes
Park average	**PEP-PA**	Yes	No	No	Yes	Yes
Representative WTGs average	**PEP-PR**	Yes	No	No	Yes	Yes
Neighboring WTGs	**PEP-N**	No	Yes	No	Yes	Yes

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